# Practices, Policies and Technology of Storm and Combined Sewers in Foreign Countries

## Research Report No. 45

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**Research Program for the Abatement of Municipal Pollution under Provisions of the Canada-Ontario Agreement on Great Lakes Water Quality**

CANADA-ONTARIO AGREEMENT

RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies carried out in this program through in-house projects by both Environment Canada and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

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# PRACTICES, POLICIES AND TECHNOLOGY OF STORM AND COMBINED SEWERS IN FOREIGN COUNTRIES

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RESEARCH PROGRAM FOR THE ABATEMENT
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## ABSTRACT

This study was undertaken to evaluate pollution problems associated with storm sewer discharges and combined sewer overflows in several European countries and the United States. Current methods used to abate pollution from these sources and research underway to develop new methods were also investigated.

Since the magnitude of the problem and the approaches to its solution vary in each country according to the relationships between various levels of government, citizen action groups, industry and research groups, it was necessary to review the governmental structures, historical aspects, and present design criteria for all contributory features of storm and combined sewers in the countries studied.

Questionnaires were distributed to local authorities, government departments, research organizations and consulting engineers in Sweden, France, the United Kingdom, Germany and Switzerland. In addition, research engineers visited installations in each country and interviewed key personnel.

This report reviews the information obtained during the study and assesses the various methods of combatting pollution from storm and combined sewers, both in the context of the countries concerned, and in relation to the Canadian situation.

# RÉSUMÉ

La présente étude avait pour objet l'évaluation des cas de pollution que l'on rencontre dans plusieurs pays européens et aux Etats-Unis, et qui sont causés par les égouts pluviaux et unitaires. Elle devait également donner l'occasion d'examiner, les méthodes actuellement utilisées pour réduire ce genre pollution ainsi que les recherches qui se font actuellement pour découvrir de nouvelles méthodes.

L'ampleur du problème et la façon de le résoudre varient d'un pays à l'autre en fonction des rapports existant entre les divers paliers de gouvernements, les groupes de citoyens, l'industrie et les chercheurs; aussi a-t-on jugé nécessaire d'examiner les structures gouvernementales, le côté historique et les critères actuels de sélection touchant de près ou de loin à tous les égouts pluviaux et unitaires des pays en question.

On a donc fait parvenir des questionnaires à divers ministères autorités locales, groupes de recherche et ingénieurs-conseils de la Suède, de la France et du Royaume-Uni d'Allemagne et de la Suisse. De plus, des ingénieurs ont visité des installations de chacun de ces pays et questionné leurs responsables.

Le présent rapport traite des données recueillies à cette occasion et évalue les diverses méthodes employées dans la lutte contre la pollution attribuable aux égouts pluviaux et unitaires, compte tenu de la situation prévalant dans les pays étudiés et en rapport avec ce qui se fait au Canada.

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## CONCLUSIONS

The present status of storm water practices in each of the countries studied is summarized in the following.

### United States

A massive pollution correction program with a target date of 1983 has been established. The interim goal is the protection of fish, shellfish and wildlife and recreation in or on the water. The Federal Government has taken the lead; it has passed the necessary laws and approved the necessary funding which will enable it to work with State or Interstate authorities in achieving the necessary goals. A large volume of research has been and is being undertaken, and the problem of storm water management is now better understood in the United States than in any other country.

This program is proceeding more slowly than was anticipated, but a very commendable start has been made and, while the rate of progress may be slow, it is quite apparent that the impetus has been developed and will be maintained until the goals have been achieved.

### Sweden

Considerable progress has been made in Sweden in controlling the pollution from sanitary and industrial sewage, and the country is now coming to grips with the storm water problem. Considerable effort has been expended in keeping abreast of foreign research and in seeking unusual solutions to problems which are peculiar to the Scandinavian environment.

The central government is instrumental in setting the standards for policies and ensuring adequate funding for research projects.

### France

The pollution problems in France have not been considered as critical as in other countries because other needs for reconstruction have, of necessity, taken priority. A massive program for sanitary sewerage treatment facility construction is also in progress; consequently, few funds are available for the correction of the storm water pollution problem, which is relatively insignificant in comparison to that of the sanitary system.

## United Kingdom

The relatively limited water resources of the United Kingdom have become severely strained by pollution from various sources and a continuous effort has been made in the past several years to clean up both sanitary and industrial pollution. A considerable improvement has been effected, and this, together with the extensive coastline, has created a situation where the storm water flooding is regarded as being more critical than the storm water pollution.

The management of the water resources in the country has been entirely de-centralized so that each area is now entirely responsible for its own water management. It is also apparent from the mapping of river pollution that the most severe problems are generally restricted to the industrial midlands.

## Germany

The pollution problems of the waterways of Germany have been evident in the industrialized, densely populated sections of the country. Considerable improvements have been effected, but here too, the demands of post war reconstruction have resulted in some delay in construction of new facilities. The balance of power between the Federal and the Lander governments has caused a delay in the establishment of a unified program for the entire country. Even so, the significance of storm water and overflow pollution is recognized federally and the government is both pressing for the construction of more detention tanks and making funds available for extensive research.

Where conditions are most severe, the formation of conservation authorities by contiguous local authorities has resulted in the construction of treatment plants, the control of pollution and, in at least one case, the treatment of an entire river.

## Switzerland

Surface water pollution in Switzerland has for many years been kept very much under control. The Federal and Cantonal governments, by virtue of a grant system which enables any municipality to construct whatever treatment facility might be appropriate to its circumstance,

has enabled the entire country to be maintained in a relatively clean condition. The awareness of the need to control pollution and the desire to maintain an attractive country has required industries to provide covered storage for unsightly and surface polluting materials, and generally to control discharges and treat them as appropriate.

Summarizing the above, it is apparent that each country has recognized a serious pollution problem and has tackled that problem in a manner which clears up the worst offender first, but only in relation to a priority established relative to the country's state of well-being.

It is of interest to examine where the different countries have a common concern and, subsequently, to review particular achievements in each country.

1. <u>Rainfall and Storm Data</u>. There is considerable concern that present data are inadequate; research is being directed towards a better understanding of storm intensities, directions, frequencies and movements. The need to break down areas into subcatchments has been recognized. In the U.K. the meteorological office has sufficient data to supply appropriate intensities for storms of whatever duration requested, for whatever return period required, for any part of the country defined in a grid of 10 km squares. Ongoing research is involved with intensive catchment gauging to more closely and accurately relate rainfall to runoff in undeveloped, developing and urban areas.

2. <u>Entry Time</u>. It has universally been assumed that the aim in designing storm sewerage systems was to get the rainfall into the sewer and out of the area in the shortest possible time. This principle is now being questioned, both from the aspect of depleted groundwater, and the creation of greater flood intensities. Various possibilities are being examined.

   In Sweden, it has been suggested that there are advantages in ensuring that runoff remains outside the sewer by considering the use of open ditch drainage in urban areas, and porous pavements, which are also used in Germany. In the U.K. and to a lesser extent

in France, effective use has been made of shallow valley storage within the urban areas both to attenuate the runoff, to effect a simple settlement treatment, and to provide a beneficial use for recreation. In the U.S. extensive use of storm attenuation storage has been implemented in various areas when runoff from roofs has been restricted, redeveloped downtown areas have been constructed with on-site storage and subdivisions designed attractively around the principle of flood-flow ponding. However, concern has been expressed that there is no control over the discharges from these in-situ storages after construction; thus, the coincidence of such discharges may themselves create a flood hazard. Further problems are anticipated with the maintenance which will be required by the storage and retention devices which are in private ownership and on private property.

Separately, work is being directed towards developing more accurate figures for time of entry and runoff patterns from different surfaces under different circumstances.

3. Sewer Storage Capacity. The computer is enabling sewer systems in the larger urban areas to be utilized to their maximum capability by diversion and storage within the system. Such systems are now in use in France, Germany and the United States. In Sweden, the centralization of sewage treatment plants and the construction of deep rock collector sewer systems has provided the means to store and, subsequently, to treat combined flows. However, the Federal approach is still to separate sewers and to treat storm sewage only if the recipient conditions are unsuitable.

4. Sewer Design. With the exception of some parts of Germany and France, the computer has become the universal design tool for sewer systems for larger urban areas. The availability of the RRL program in the U.K. has led to more rapid adoption of computer design than might otherwise have occurred. There are still some problems, but the programs are being improved and there can be little doubt that the value of the computer as a design tool is fully appreciated.

5. <u>Overflows</u>. The most common overflow type is the weir and improper setting is frequently the cause of excess combined sewer overflows. The vortex regulator developed in the U.K. and U.S. provides a means whereby the larger solids in suspension can be separated from the overflowing effluent without the need for extensive land requirements.

6. <u>Combined Sewers</u>. It has been universally acknowledged that the cost of separating combined sewers in existing urban areas is a financial burden too large to contemplate. While most new construction is for separate sewers, in Germany combined sewers are still being constructed based on the assumption that ultimately the majority of sewer flows will be treated, except in low-lying areas where pumping is required.

7. <u>Non-Gravity Sewers</u>. Discounting the force mains found in all sewer systems, there were very few examples of pressure sewer systems and these were generally economically justified for topographic reasons.

8. <u>Storm Water Storage</u>. In Europe, it has been fairly common to construct storm water overflow tanks at sewage treatment plants, and subsequently to treat all of the stored flows. Increasing development, however, has overloaded sewer systems, causing more frequent use of existing overflows. This has highlighted the need for a more accurate setting of the overflow, and also created a demand for storage and retrieval of the overflow for treatment in the case of combined sewers. For storm sewers, research in the U.S. has been directed at developing high turbulence settlement and chlorination so that the overflow is markedly improved before discharge.

9. <u>Treatment Plants</u>. Although not directly involved with storm sewerage it is of interest to note that in Sweden, the construction grant from the Federal government is higher if the degree of treatment is higher; while in France, the grants for the operation of sewage treatment plants are based on the efficiency. In Switzerland, the Federal grant is related inversely to the ability of the

local authority to pay. The principle in Germany is that the polluter pays, while in the U.S. the grants are identical but the degree of treatment is determined by the target dates of the 1972 Act.

10. <u>Organization and Administration</u>. In Switzerland, Sweden, Germany and France, the direction of the environmental clean up campaign is administered by the Federal Government. In Switzerland, such direction is by agreement with the Cantonal governments, while in Germany it is proving time-consuming to develop a unified Federal program due to the strength of the Lander governments. In the areas of Germany where local pollution is severe, conservation authorities have been formed having the power to monitor effluent quality and levy charges for the construction of the necessary facilities and treatment plants. This has placed the control locally, where the need is greatest and, in this respect, may be likened to the system of local management established in the U.K. and the principle of the responsible authority designated locally in the U.S.

It is worth noting that only Sweden and the United States have established clean up programs which are linked to target dates.

11. <u>Flooding</u>. The problem of flooding is twofold in the heavily developed urban areas. The sewer system is "known" and the locations of relief interceptor sewers have been identified, if not yet constructed. The design intensities have frequently become familiar through use and the degree of flooding and its frequency can be forecast with moderate accuracy. This situation is, however, being improved as the computer is refined as a design tool.

In the suburban, rural and developing areas, no such familiarity exists and, in the past, construction has proceeded in areas subsequently found to be flood plains. The consequences have frequently been serious and often disastrous. However, in these investigations comment was made that, at the municipal level, very little had been done to investigate and establish criteria relevant

to the cost and benefits of flood alleviation. The only report obtained on this aspect was produced by the Local Government Operational Research Unit in the U.K. [43]. A similar report is in preparation with respect to storm sewerage.

12. Research. One of the features very evident in the investigations both in Europe and North America was the awareness that research work in this field should be better coordinated. Thus, in Scandinavia, Nordforsk is providing international coordination for Norway, Sweden, Denmark and Finland. In the U.K., all research on storm water management is being brought under the direction of a single committee, but many multidisciplinary studies are already in hand. In the U.S. the EPA is providing the funding and, thereby the coordination, for research matters.

## RECOMMENDATIONS

The recommendations which follow have been divided into the categories of quantity, quality and management, but it is recognized that certain proposals would not be so isolated in practice.

### Quantity

1. The complete division of storm and sanitary sewers in new and developing areas and the unregulated discharge of storm waters into natural water courses should be examined in relation to their potentiality for increasing flood hazards.

2. Within certain critical areas, maps should be produced defining the flood plains of the larger waterways, and the contributing areas should be identified.

3. The construction of new developments should be permitted on the basis that the storm drainage shall not create a flood hazard downstream. This may require that the runoff be restricted to that of the undeveloped property.

4. The availability of rainfall records should be reviewed and joint discussions held to ensure the establishment of sufficient additional stations for the collection of data regarding storm intensities, durations and movements.

5. When a new town or a large urban development is proceeding under the direction of the federal or provincial government, the opportunity should be taken to design experimental drainage sections, incorporating in-line storage, combined sewers, overflow treatment, etc. Evaluation procedures should be established so that drainage criteria may be developed.

6. Investigations should be undertaken to evaluate how a drainage authority might control the maintenance and adjustments required on schemes where private, industrial or commercial developments detain water on-site and release it subsequent to storms.

7. An investigation should be undertaken at the municipal level to derive economic criteria relating the cost of flood protection to the benefits. It should be possible to produce criteria which would assist the designer to optimize the cost/benefit ratio.

Quality

1. Since it is almost universally accepted that the cost of separating existing combined sewers is too high to contemplate, and these are generally the main drainage arteries of the older downtown areas, they represent one of the largest sources of surface drainage water pollution. It is of prime importance, therefore, that a policy be developed regarding the treatment of the combined overflows. This could involve solids separation, storage and treatment. The methods most suitable and appropriate to each location would require special consideration. Existing research should be evaluated to determine methods and structures which could presently be used and research should be extended in those areas which seem promising.

2. At the present time, downtown streets are cleaned once or twice per week and in the suburbs, just occasionally. Variations occur in street sanitation: some are washed, some are sprayed, some have no traps on the catch basins. It is suggested that, in suitable areas, separate sewer system outflows be monitored by continuous sampling initiated during storms, and that the same procedure be carried out simultaneously in two contiguous areas, each having differing street cleaning procedures and intensities. It should then be possible to assess the cost and benefit of street cleaning and equate them ultimately with storm water treatment costs to determine the optimum solution.

3. It would seem appropriate to review the costs and effects of the construction of separate sewer systems with immediate discharge of storm flow to water courses, and to compare them with other alternatives such as combined systems with overflow treatment, flow detention and treatment, with a view to determining appropriate procedures.

4. Existing research should be reviewed and new research implemented as necessary to identify the problems of treatment of combined sewage overflows and storm flows at treatment plants.

5. Maps should be produced and made available defining the extent of critically polluted surface waters.

6. The polluting effect of storm runoff from new construction and new urban development should be accounted for by consideration of the annual mass of pollutants likely to be discharged to the recipient stream.

<u>Management</u>

1. The management of storm water flooding and quality should be reviewed generally to examine how best it should be coordinated.

2. The possibility should be considered that storm drainage and flood protection should be self-financing and that storm drainage be deemed a service similar to a water supply or a sanitary sewer. Charges might be made to the householder and the industrial development in accordance with a formula relating runoff rate to the area occupied. In this way, the developer providing the maximum retention, and thereby the minimum rate of runoff, would pay less than a developer holding the least water on-site and discharging at the maximum permitted rate to the watershed.

3. Storm drainage design criteria should be collected and reviewed and a manual published incorporating up-to-date concepts. Subsequent revisions would be made as appropriate. Such a manual, together with a map of critical receiving waters, would enable the drainage criteria for any area to be readily recognized.

4. Considerable effort is already being made to ensure that the hydraulic design of sewer networks is undertaken in the most expeditious manner, using computers to produce the optimum result.
   It is now essential that all secondary benefits and costs should be identified. These might include improved landscaping on smaller flood control waterways, recreational benefits from stored flood water, improved quality of smaller natural streams, groundwater replenishment in developing urban areas and lower water treatment costs.

The science of storm water management, drainage and flood control is entering a new era. It is necessary that those responsible for it be provided with the financial backing necessary to achieve the desired results. Money spent in the early stages on applied research, on-site investigations and proper planning will help to ensure that the desired results are achieved at minimum final cost.

# 1. INTRODUCTION

The earliest urban centres were established in response to trade and commercial requirements, frequently on a lakeshore, but always with easy access to a reliable, good quality water supply. The stream, river or lake usually served many purposes and eventually the discharge of raw wastes created problems. The problems, which originally seemed trivial since the resource was apparently unlimited, have slowly but surely increased in intensity. Across Europe and North America, an awareness has developed of the need to conserve the environment, as each country has observed a reduction in marine life and a restriction on the availability of natural recreational waters near the urban centres.

Storm drainage is neither the largest nor the worst offender, but the limited resources of the earliest developers have left a residual of combined sewers, conduited streams and overflows which are inadequate for modern rates of development and densities of traffic. Even the separated storm sewers have deteriorated in quality to the equivalent of a treated sanitary effluent, and so a real need has arisen to review what steps should now be taken to ensure the correction of the problem by the appropriate method.

The objectives of this study included, but were not necessarily limited to, the following major items:

- An investigation of the order of magnitude of pollution problems associated with storm sewer discharge and combined sewer overflow.
- A review of the magnitude, direction and responsibility for research being undertaken.
- An examination of the statutory policies governing storm discharges and overflows, and of the research and/or philosophy which led to the introduction of present policies and regulations, with consideration of the potential influence on these controls of research currently being undertaken.
- A study of present design practices, covering methods of problem identification; methods of solving the problems once identified; evaluation of overflow control techniques, and interception and

transmission methods; municipal maintenance practices and their effects on total pollution; the quantity and quality of pollutants discharged and the effect of maintenance practices thereon; operation of treatment plants, and effect of discharges upon the receiving waters.

- A review of the means of financing sewer and drainage systems and an assessment of the influence that the methods of financing have on regulatory directives and on design.
- An appreciation of the findings in each country, as well as a comparative appreciation of the results with possible influence on Canadian practice.

# 2. UNITED STATES

## 2.1 Governmental Structure

The government of the United States is divided into a large number of independent and interdependent units. Legislative authority is exercised by the Federal Congress, each of the 50 states, and thousands of local jurisdictions at the county or city level. Taxes are levied by each of these governmental entities, and they are, to a great extent, independent of each other. However, there is a definite hierarchy in the legislative arena, and certain powers have been preempted, first by the federal government and to a lesser degree by the states. The local governments, therefore, are somewhat restricted in the fields of their authority.

The administrative function of government is separated from the legislative at all levels. In addition to the various federal, state and local agencies which are direct counterparts of the legislative bodies, there are a number of groups which do not fit the traditional breakdown. Regional planning agencies are neither local nor state, but have certain characteristics of both. These agencies generally depend on both state and local governments for funding, and their role is frequently hampered by a lack of real power. On the interstate level, a similar group of agencies has been created by compact between state and federal governments. These agencies, which often are referred to as interstate commissions, combine characteristics and powers of state and federal governments.

Problems related to water supply, water quality and flood control have been relegated to every level of the government. However, there are certain areas which have become the prerogative of particular government structures, and encroachment of one level of government upon the domain of another is not taken lightly. For example, the design and construction of waste treatment facilities has been the traditional preserve of local government, although the trend toward regionalization is shifting this function more to regional agencies, or, in a few cases, to the state. However, the federal government plays little direct part in design and construction except through its control of construction grants money. Even this influence is an indirect one; the actual design and construction are very much local or regional control.

Similarly, local interests control land use policy almost entirely. This means that nonpoint pollution problems are local ones, administratively. The federal government rejected a move to create a national land use policy in 1974, and the states also have been wary of such involvement.

Navigational use of waterways has long been acknowledged as a federal preserve. In fact, many of the early attempts of the federal government to move into the water quality field were justified by its navigational powers.

Research activities are not restricted by law to any level of government, but the federal government is dominant in this area. Well over 90 percent of all research dollars are of federal origin, although some are expended through the state university systems. A few programs are funded directly by the states, and of course some privately sponsored research bears on water quality, but it is safe to say that it is preponderantly federal.

All levels of government have dealt with the problems of standards for water supply, waste effluents and receiving water quality, but these areas have now moved into the federal domain. State, local and other agencies have exhibited less than strict attitudes in this area, and the authority is now federal.

In summary, the government of the United States is very diverse, with functions held by federal state, local, regional and interstate agencies. The trend appears to be toward more federal control, but many areas are still in other jurisdictions, and it appears that this situation will persist for the foreseeable future.

## 2.2 Historical Background

The abundance of natural waters throughout most of the United States was so great that very little attention was given to sewers or sewer practices until the latter part of the nineteenth century. This should not imply that there was no problem, only that there was no solution. Most urban areas were greatly afflicted with contaminated waters; it is reported that odours from the Potomac River were so strong in mid-nineteenth century Washington that the various Presidents were reluctant to

spend time on the White House lawn. Sewage systems developed in most major cities in the last part of the century, but no treatment was given to the waste for many years.

Industrial wastes also continued to pour untreated into the nation's waterways, and an expanding industrial society was being created. The Rivers and Harbours Act of 1899 was one of the first attempts to curb such discharges, giving primary authority to the Corps of Engineers, and establishing fines for the pollution of navigable waters. This Act lay dormant for many years; its "rediscovery" in the late 1960's greatly enhanced the arsenal of many environmental activists, and led to other legislation.

The basis for all pollution legislation in the United States is the police powers which are vested in the individual states by the Constitution. Thus, all such legislation at the federal level has been tied to the prevention of nuisance or to the implementation of health practices under the umbrella of the regulation of interstate commerce. But the primary authority to curb and control pollution still rests with the states, and even in those areas where the federal government is very active, it has shown a marked reluctance to alter the state supremacy.

There was no appreciable federal action in pollution abatement until 1948, and combined sewers were the favoured collector system. Policy was set exclusively by the states or by local agencies acting under the authority of the states. A number of facilities were federally financed but this was an economic move to combat the depression of the 1930's, not an attempt to enter the pollution field.

The first Federal Water Pollution Control Act was passed in 1948. It was limited strictly to interstate waters, and it provided for action only when public health was endangered. Any state was empowered to veto federal enforcement, and the Act generally was not useful for enforcement purposes. However, the Act set up a limited planning and research function for the Surgeon General, and it can be counted as the beginning of federal activity in this area.

Construction grants were authorized by the Water Pollution Control Act Amendments of 1956. Although the federal contribution was only 30 percent, it showed a clear interest in pollution abatement. In

1961, administration of the Act was transferred to the Department of Health, Education and Welfare.

The year 1965 marks the first efforts to require standards approved by the federal government. The Water Quality Act of 1965 was limited to interstate waters, and the enforcement procedures were so cumbersome as to be little used, but it established the position of the federal government as the arbiter in pollution cases.

The enforcement program became effective with the Water Quality Improvement Act of 1970. It made federal permits mandatory for discharge to navigable waters, or, if the federal permit was not obtained, the state was required to certify that water quality standards were not violated. Thus, attention was focused on enforcement of standards and the priority was established that pollution control was indeed an important consideration in municipal and industrial development.

The federal government assumed a major role in pollution abatement with the 1972 Amendments to the Water Pollution Control Act. This Act set the elimination of water pollution as a national priority and put the federal government squarely into planning, construction and enforcement. The states still are major entities in the process, but the role of the federal government is now a powerful one. Specific elements of the new Act are given in more detail in Section 2.4.

## 2.3 Authorities

Primary authority in most matters of water pollution control rests with the Environmental Protection Agency (EPA) at the federal level. Each state, in turn, has a state EPA which may be called by a variety of names. Common appellations are Department of Natural Resources, Department of Pollution Control, State Water Resources Control Board, etc. In some states, functions related to water pollution control are divided among several agencies, perhaps with planning being carried out by one group, enforcement by another.

Other federal agencies besides EPA have significant programs also. The U.S. Army Corps of Engineers still has responsibility for protection of navigable waters, and this has been interpreted very broadly as extending into water quality at several levels. For example, the Corps

is conducting urban studies programs in a number of major metropolitan areas; these are comprehensive planning studies which overlap or supersede several EPA programs. The Corps has used both its navigable waters and flood control powers to move strongly in water quality planning.

Similarly, the Department of the Interior, which exercised many of the functions of EPA prior to that agency's creation, continues a strong program in water quality affairs. Interior serves as the umbrella for several quasi-independent agencies such as the Bureau of Reclamation, the U.S. Geological Survey, the National Park Service and the Office of Water Resources Technology. Each of these agencies has programs which affect urban water quality significantly; none has the broad, nationwide effect of EPA or the Corps. Other Interior agencies are even more specialized, but they do have some topical programs. The Bureau of Sports Fisheries, the Soil Conservation Service and the Bureau of Land Management are some of these.

Each branch of the armed services is important in pollution control because these organizations, the Army, Air Force, Navy, Marines and Coast Guard, maintain large bases in metropolitan areas. They are exempted from all state controls and many federal ones, and until recently, did not exhibit much interest in their pollution problems. This situation is changing rapidly, and the military has become quite conscientious in cooperating with state and local authorities. Nevertheless, much of their cooperation is voluntary, not required by law. Incidentally, it should be noted that the water pollution activities of the Army Corps of Engineers are civil functions, not military ones, and the administration of these two aspects is almost 100 percent separate and independent.

To complicate this already diverse picture further, the Department of Justice must be mentioned. Whenever litigation is required, Justice will be brought into the picture. If, for example, EPA is unable to bring an industry into line, legal pursuit of the matter will go through Justice.

Several interstate agencies have been set up to deal with water problems, and the expansion of urban areas has resulted in almost all interstate agencies being faced with storm water problems. Each interstate agency is a special case, and the scope of this work permits

only a cursory review of them. The most powerful are the Delaware River Basin Commission (DRBC) and the Tennessee Valley Authority (TVA). The latter is really a public corporation, not an agency. But interstate agencies can plan, conduct research, construct facilities (sometimes) and provide enforcement. Their power is, in narrow areas, greater than that of the states they cover.

National and state policy regarding storm runoff is set by law, at the highest level, and by directive from one or more of the agencies mentioned above. Each agency interprets the law as it affects the programs within the agency and as it affects the agency's regulation of private industry and government. An example of this process is the Federal Permit System for waste discharges.

Responsibility for issuing waste discharge permits to municipalities and industries is given to EPA by law. The law requires that EPA maintain such a program and outlines the process. EPA, interpreting the law, issues guidelines and procedures for applying for a permit and defines the steps which a prospective discharger must take. The sequence consists of the following steps:

1. Discharger prepares draft permit application,
2. Public hearing is held,
3. Discharger revises permit application,
4. EPA issues or denies permit,
5. If denied, discharger appeals to EPA,
6. EPA issues or denies permit on appeal, and
7. Discharger seeks adjudicatory hearing in Federal Court.

Each of these steps must be followed in order; the discharger cannot seek relief in the courts until the first six steps have been completed. This process for permits is typical of the relationship between industry, state and municipal governments and the federal agencies and court system. The agencies act, on a day-to-day basis, as the legislative and administrative bodies and as the court system. It is only when the processes within the agency have been exhausted that the assistance of the court system can be sought. A similar situation exists within the state regarding state regulatory agencies.

## 2.4 Pertinent Legislation

The enabling legislation which guides the U.S. Environmental Protection Agency (EPA) in the administration of water pollution control is the Federal Water Pollution Control Amendments (FWPCA) of 1972 (Public Law 92-500, Passed October 18, 1972). This legislation revamped the entire program for abatement of pollution and created a powerful new enforcement vehicle, the National Pollution Elimination Systems (NPDES) permits, for all significant dischargers. The overall goals of the program were unchanged from goals of the previous legislation cited above. However, the detail in this law is more rigorous and procedures are set up for citizen involvement in all facets of water quality management.

The state remains the level of government primarily responsible for preventing, reducing and eliminating pollution and for planning and use of land and water resources. The federal role continues to be one of support, aid and technical and financial assistance to the states, interstate agencies and municipalities. Local government continues to be responsible for initiation of abatement actions (planning and construction of facilities).

The focal point of the FWPCA is the NPDES permit program. All dischargers were to have permits by January 1, 1975 (this deadline was met for all large industrial dischargers; permitting of smaller dischargers is continuing). The basic philosophy is control at the source by individual dischargers before release to the receiving streams. The control mechanism or process must be selected such that instream water quality standards are met. Permits are to be issued for five years, although interim permits for shorter periods have been issued.

A minimum level of treatment is specified for all municipal and industrial dischargers. No distinction is made in the NPDES process between these types of dischargers. However, most EPA attention has been addressed to the industrial sector in the issuance of NPDES permits. Municipal or publicly owned treatment facilities are to provide at least secondary treatment on all discharges by July 1, 1977 and to upgrade to at least alternative waste management techniques before July 1, 1983. Privately owned point source control facilities are to apply the best practicable control technology currently available by July 1, 1977 and

to apply the best available technology economically achievable by July 1, 1983. EPA has defined these two levels for all major industrial categories. The framework was to define effluent standards based on production for all two-digit Standard Industrial Classifications (SIC). An example of this is the steam electric power generating industry classification.

The criterion for determining the effluent standard is, of course, the resulting instream water quality, which is compared to the federal state water quality standards. The current permits are determined by estimating water quality if the minimum effluent standards are applied. Should unacceptable quality result, then a more stringent level of effluent standard would be specified. All stream segments where the more stringent levels are required are denoted as water quality limited. The most stringent effluent standard possible is total elimination of discharge. As yet this level has not been specified.

Stream water quality standards prior to passage of the FWPCA were based on designated stream uses. Examples of these uses are raw drinking water supply, fish and wildlife propagation, industrial process water, navigation, agricultural water supply, water contact recreation and noncontact recreation. These use designations still apply. Water quality standards are to be reviewed at least every three years. The overall goal is to upgrade the standards such that, by 1983, an interim goal of water quality may be attained which provides for protection and propagation of fish, shellfish and wildlife, and for recreation in and on the water.

Water quality management planning continues to be stressed in EPA's programs. The state is required to begin a continuing planning process encompassing both point and nonpoint control programs. Monitoring and technical support programs are included. This continuing planning program will produce basin plans for the overall management of pollution abatement programs. Water quality segments are identified together with remedial actions required to restore the quality.

Remedial action can take the form of industrial permit requirements or of municipal facilities construction. All municipal and industrial treatment improvements required are given priorities for action. These

priorities are considered in the scheduling of permit issuance and are also considered in determining recipients of Federal Construction Grants Assistance in a given fiscal year.

The Construction Grants Program has evolved into a three-step program involving Facilities Planning (Step 1), Facilities Design (Step 2), and Construction (Step 3). The planning considered here is directed toward identifying future waste quantities and quality, siting the new facilities, and evaluating the means of attaining the necessary effluent standards.

The factors which are considered in the Step 1 plans include cost effectiveness, unit process selection, identification of future service areas, operation and maintenance needs, infiltration/inflow analysis, evaluation of joint municipal/industrial treatment and evaluation of sludge disposal/reclamation procedures. In the cost effectiveness analysis, regionalization alternatives are considered and staged construction options are studied. Alternative solutions are developed, and costs are estimated and compared. Implementation strategy is developed and the most cost effective plan selected.

Another output of the basin plans is the identification of urban/industrial complexes where an area-wide waste treatment approach should be undertaken. Facilities Planning is directed to remedial solutions; Area-wide Waste Treatment Management Planning is forward-looking, directing attention at land use and nonpoint pollution questions, as well as facilities location/sizing.

Facilities Planning is undertaken by the community which owns the treatment plant. Area-wide Planning is undertaken by an agency which has locally elected officials responsible for the decision-making. Typical area-wide agencies are local councils of governments whose Board of Directors is composed of heads of local governmental units. This approach enables the urban centre city to participate jointly with suburban communities and rural counties in the common goal of controlling their respective destinies.

The Area-wide Planning Program will identify future actions whereby pollution abatement in the urban area can move from the reaction stage to the planned action stage. Once these plans are developed, an

implementing agency is to be formed which will carry out the plan. This agency begins to take the shape of a regional government which supersedes the present city/town arrangement at the local level. Nashville, Tennessee, is already using this approach and the future direction is likely to be toward regional government.

There are a number of other important areas in the FWPCA of 1972. Oil pollution, pesticides and ocean dumping areas are addressed. A major item is the extensive research program that continues to explore new and improved methods of treatment, disposal and reclamation of wastes as well as institutional and managerial options for waste management.

The Council on Environmental Quality (CEQ) was established by the National Environmental Policy Act of 1970 as a small policy making and coordinating agency within the Executive Office of the President. CEQ's responsibilities are those of advising the President on environmental matters, issuing an annual report on environmental quality and coordinating the Environmental Impact Statement process set up by Section 102 of the Act. The staff is deliberately small to emphasize the coordinating. No bureaucracy is intended to be created. Rather, each agency is to perform environmental analyses of alternatives as part of its normal decision making process.

The impact of the Act has been great. Many federal agencies have had their actions stopped or delayed because the courts have found that their decision making processes do not adequately consider the evaluation of alternatives from an environmental viewpoint. The Environmental Impact Statement process is designed to give many private groups and public agencies the right to comment on other agencies' proposed actions before implementation. The action agency can ignore comments from other agencies and the commenting agency is powerless to force a change. However, all comments are public and the commenting agency's objections can form the basis of a suit in court brought about by a private group.

The aim of the legislation is clear. The integrity of the water courses is to be restored and maintained.

The areas of major water quality control problems have been identified and the most capable organization within each area has been designated to develop the program of improvement. Environmental pro-

tection is supported by strong federal/state programs that are adequately funded.

The legislation is strong and well constructed. The Congress has created a good vehicle to improve the quality of streams in the United States. Its implementation is a monumental undertaking which has been only partially successful thus far, but which will undoubtedly achieve its goals, be it somewhat slower than was originally anticipated.

## 2.5 Financial Considerations

The grants program takes the form of matching grants to states, associations of municipalities, municipalities and, occasionally, private organizations (industries). With the notable exception of the Area-wide Waste Treatment Planning Program, all grants are partial federal funding for desired actions where the state or local agency must put up some of the money (a match) and meet federal requirements (or regulations) by bringing the state or local programs to some minimum level required by the federal program.

The bellwether of the grants program for water pollution control is the Construction Grants Program, which has experienced accelerating emphasis as evidenced by both increased funding and strengthening of the program's requirements. The increased funding levels are tabulated in Table 1 below.

TABLE 1. WATER POLLUTION CONSTRUCTION FUNDING LEVELS IN THE U.S.

| Fiscal Year | Appropriation (Millions of Dollars) |
|---|---|
| 1966 | 121 |
| 1967 | 150 |
| 1968 | 203 |
| 1969 | 214 |
| 1970 | 800 |
| 1971 | 1,000 |
| 1972 | 1,650 |
| 1973 | 5,000 |
| 1974 | 6,000 |
| 1975 | 7,000 |

In 1973, 1974 and 1975 appropriations were partially impounded by the President and are being released now as a result of state suits against the federal government.

The current financial arrangements are a 75 percent federal share to be matched by 25 percent local share. Some states are providing some portion of the local share. For instance, Maryland provides 12.5 percent of the total eligible cost. Payments of federal and state shares are made based on completion of the project.

Prior to the passage of the FWPCA of 1972, the eligible costs were those of planning and construction major interceptors (15" or greater) and waste treatment plants. The eligible costs have been expanded to include those for all collection and treatment works, including sanitary wastes, storm water runoff and waste in combined sanitary/storm sewer systems. EPA has found it necessary to attach priorities to types of projects and is currently funding treatment facilities for sanitary wastes and major sanitary interceptors.

The grant recipient is the municipality. Only its costs are reimbursed and the municipality must assure the federal government that a number of factors will be given attention during and after construction of the facilities. The sewer services are not to be denied to any group because of race, creed or colour. The facility is to be operated and maintained with adequate staff to ensure good future operation. All construction will provide at least secondary treatment for all water currently received by the municipality. All industries that discharge to the facility will pay their fair share of the cost of construction, maintenance and operation of the facility. The industries are to provide adequate pretreatment before discharging to the municipal system. Cost effectiveness and flexibility are to be considered in selection of treatment sites, unit treatment processes, and effluent discharge points. Interceptors cannot be funded unless adequate treatment exists. Future capacity in new facilities is limited to reasonable projections.

The major problems with the Construction Grants Program have been the transferral of responsibility to the federal level and the misdirection of funds into lower priority construction. The federal government has consistently promised more grant money than it has delivered.

The municipality is pushed by state and federal pressure into designing a treatment facility. Prior to 1973, all costs for the initial phases such as plan and specification preparation were borne by the municipality. The first federal grant payment was received when the actual construction was 25 percent complete. This procedure resulted in many municipalities bearing the initial cost and then waiting for one to three years before being reimbursed. Any state trying to force a municipality to build could not be certain that the next year's funding would be available. Inaction often resulted.

The procedure for distributing federal funds to each state was based on a specific formula. The state would then designate those municipal projects that it felt were high priority and would begin construction during that fiscal year. The state attempted to use all available money each year. Large urban projects were often too expensive to be funded all at once without using all the state's money for one project. Therefore, a number of small community projects were always ready to go and funded. The large projects were funded in pieces and construction stretched out over years. The result was a concentration of funds into rural or small urban areas, with delayed construction or no funds at all in large urban areas. This became a rural solution in an urbanizing society.

A small grant program has been in existence for cost sharing of state administrative programs for water pollution control. The federal government was to fund between 1/3 and 2/3 of the total administrative costs, but state programs have grown rapidly during the last decade and federal funding has not kept pace. The more progressive states are carrying 95 percent of the cost, while some slower states are paying only 33 percent. The current funding for this program is $40 million per year.

The Area-wide Waste Treatment Planning Program is a forward-looking, 100 percent federally funded urban planning program which is intended to explore the entire range of pollution control options in order to protect the quality of U.S. waters. The program is to have responsibility vested in a local agency controlled by locally elected officials. Two-year planning studies are to be undertaken comparing point (facilities) control measures to nonpoint (institutional) strategies.

Water quality management is the purpose, but land use and growth controls are likely to be the implementation vehicle.

Each year, a small number of industrial treatment process demonstration grants are awarded to industries seeking new treatment solutions to their problems. EPA is using the 75 percent federal, 25 percent private cost sharing research program to demonstrate technology for particular industrial problems. If the technology performs as expected, then other industrial facilities are more likely to adopt it to solve their own problems.

## 2.6 Standards

As mentioned earlier, the question of water quality standards has been the source of a great deal of controversy in the United States. The only acknowledged power was vested in the individual states, but the states were very ineffective in setting and enforcing standards. However, the federal government has gradually forced state action, and it can now be said that a fairly coherent program of standards now exists. The basic authority still rests with the states, but the federal government is active at all levels and is the motivating factor in much of the state action.

A distinction has been made between effluent standards which regulate point sources from industry and municipalities, and stream standards which may impact both point and nonpoint sources. Storm water, of course, may be either point or nonpoint, depending upon whether or not a collection system exists. From a long range viewpoint, it is obviously the receiving water standards which are of most importance; pollution of the receiving waters has been the major problem underlying all efforts to set water quality standards.

Present regulations recognize waters as either effluent limited or water quality limited. If standards imposed on the effluent will result in adequate stream quality, then the stream is said to be effluent limited and effluent standards apply. If not, the more stringent standards of stream quality are applied. Actual water quality standards have been set by the individual states and vary from place to place. The federal government has issued guidance to the states and has formally approved each state's standards.

Industry is required to provide either Best Practicable Technology (BPT) in treatment of its waste, or Best Available Technology (BAT). These are legal definitions, but they are easily understood. BPT is the best of readily available (generally understood as commercially available) methods. In other words, BPT is good, standard treatment, and it is required as a minimum level and is to be provided by July 1, 1977. If BPT is insufficient to maintain stream standards, then BAT is mandated. BAT is the best possible state-of-the-art treatment, and is to be provided by July 1, 1983. For various industries, the U.S. EPA has defined what BAT and BPT are. This has been the source of some controversy.

Nonpoint sources of pollution, either from agriculatural or unsewered urban areas, are a continuing frustration. Stream standards are applicable to nonpoint sources, in theory, but most water quality management programs are not very effective on this score. A number of current planning efforts are directed at the nonpoint problem, but actual abatement of pollution from these sources is difficult. Standards are useful in defining the goals sought, but in many instances it is impossible to make a sound technical connection between stream quality and nonpoint pollution sources. It must be concluded that standards enforcement is only one segment of the program needed for this area.

It is interesting to observe the functioning of the federal authority in taking action to control pollution despite the fact that the basic authority to enforce standards still rests with the states. There is one hundred percent federal funding of the area wide planning and seventy-five percent federal funding of the construction on a step grant basis. The end point is the improvement of the effluent and receiving water to a desired quality and the EPA does not set down standards of design or construction, nor does it have sufficient staff to undertake inspection of specifications, designs and site construction. These standards will be those established by the state, interstate or area-wide authority for each particular location.

## 2.7 Design Practices

### 2.7.1 Sanitary sewers - separate and combined

Sanitary sewers in the United States may be either separate or combined. For over 75 years, ending in the late 1960's, the majority

were combined, that is they were designed to carry both sanitary and storm flow. All major metropolitan centres have combined sewers, and they are found in most smaller cities as well. Treatment plants have been designed to handle the sanitary component only, so that the overflow of combined sewage during wet weather was part of the design. It was assumed for many years that the receiving streams were quite capable of assimilating intermittent storm flows, even though these flows contained a large quantity of raw sewage.

Design flow formulae vary widely from place to place, but most are based either on the Manning or Chezy equation. The important features in sewer design are sizing and slope; sizing to pass the expected maximum flows, slope to prevent the deposition of solids during low flows. Local design guidelines or codes are generally based on a ratio of 3:1 to 5:1 between the maximum and minimum dry weather flow, and a number of empirical relations have been developed to prevent deposition.

Most combined systems were designed using the rational method to compute peak storm flows. This technique has numerous drawbacks, but it is easy to use and served as the standard method of analysis for many years. The rational method produces only peak flows, a limitation which makes it applicable only for pipe sizing and neglects all water quality considerations. Several studies have shown it to produce large errors in design, not always on the conservative side.

Many engineers now use more sophisticated, computer-based tools for analysis and design of sewer systems. It is not appropriate here to describe these in great detail; more than 20 mathematical models have been reported in the literature to be applicable to the combined sewer problem. Those which are presently receiving the most widespread usage in the United States are :

- The Environmental Protection Agency Storm Water Management Model (SWMM).
- The Corps of Engineers Storage, Treatment, Overflow, Runoff Model (STORM).
- The British Road Research Laboratory Model (RRL).

- The Soil Conservation Service Model (SCS), and
- The Water Resources Engineers Model (WREM).

Each of these models has been used in more than five major projects, and has received acceptance in the profession. Each has been used by engineers other than its author, and has achieved a degree of recognition as a valid method.

Combined sewers fell into disfavour in the late 1960's, and the federal government stopped all grant support for them in about 1970. However, subsequent studies have indicated that combined sewers may not be as bad as formerly believed; some communities are considering treatment of almost all storm runoff. It will not be surprising, therefore, if a reversal of the trend away from combined sewers occurs.

### 2.7.2 Storm drains

A storm drain is identical to a combined sewer except that the sanitary sewage is not present. Most of the comments of the preceding section are applicable. Traditional storm drain design was based on the rational method, and designers are now turning to various mathematical models to predict design flows.

A great deal of attention has been given to the quality of runoff from separately sewered areas. The reasoning behind the development of separate sewers was to protect the receiving waters from the pollution of raw sewage spilling into them during wet weather. Recent studies have indicated that surface runoff in urban or suburban areas may be as great a source of pollutants as the sewage. Storm drains, therefore, cannot be connected directly to the receiving streams, and many new designs involve storage and treatment of all storm flows less than a given return frequency.

Communities in the United States often have their own design storm specification which may vary widely, even in a single urban region. Major cities, with their heavily urban core areas, tend to seek protection from larger storms than is generally the case with smaller cities or suburban areas. Although there is no general rule, it is common to find a five-year return frequency in major cities, and 10 or 20-year frequencies are used at times. In suburban areas, a two-year storm is the most usual design system.

### 2.7.3. Treatment facilities

Three classes of treatment facilities can be identified. There are those which receive only sanitary sewage, those receiving combined sewage, and those which (purposely) accept certain kinds of industrial effluent. The latter are special cases in which the specific character of the industrial waste must be considered.

Facilities receiving only sanitary sewage are the easiest to size, because the number of people being served is known, and there are good, or at least well accepted, estimates of per capita loading available. General design practice calls for 100 to 400 gallons per capita per day. The lower figure is representative of "strictly" sanitary sewage. The higher accounts for other entries into the system, from infiltration, roof drains, basement drains and the like. Each community will have its own estimates of its situation.

Treatment facilities for combined sewer systems have been sized traditionally by the same criteria as sanitary systems, permitting all storm flow to overflow to the receiving water. It is now required that this practice be halted, but there is no clear policy on what portion of the storm flow must be treated. Some communities have tried to capture only the first flush, say the first two or three hours of the storm, on the premise that this water contains the worst pollutants. Others have sought to store fairly large storms for subsequent treatment.

The degree of treatment required is dependent upon the particular receiving water conditions and other local factors. Secondary treatment is the most common practice for sanitary sewage. Storm runoff may receive any level from no treatment to full secondary, but most communities give very little treatment to storm runoff at this time.

Storage and detention have direct trade-offs with treatment in the control of storm water. Detention normally means the holding of storm water throughout the basin, either by use of ground cover and natural topography or by such devices as rooftop ponding and small basins. Storage usually means a larger facility at some downstream point, although the word is subject to a number of definitions. Present plans in a number of cities call for the construction of massive volumes of storage; perhaps

the most notable are Chicago and San Francisco. Both cities will use large tunnels to store storm water for later treatment. Also, in San Francisco, the tunnels will be used to equalize the volumes of water in several watersheds. On-site detention is planned or under study in several areas. One of the foremost in this is the Denver region where, although the Urban Drainage and Flood Control District has not adopted any legal requirements for on-site detention, its guidance has promoted its adoption by the communities within its jurisdiction. It is correct to say that storage and detention are design practices which are just now receiving widespread attention.

## 2.8 Present Situation

Storm water is receiving more attention now in the United States than it ever has in the past. Until a few years ago only the flooding aspects of storm water were considered problems. As recently as 1971, many well trained engineers were convinced that sewer separation would eliminate water quality problems resulting from storm water. The situation has reversed now, and great expenditures of time, manpower and money are being made in an effort to eliminate both quantity and quality problems.

The change in attitude can be summarized by examining two current practices.

1. Flooding: It is no longer accepted that techniques which remove water the most rapidly are the solution to flooding. Instead, practices which cause the runoff from developed areas to resemble natural runoff are often preferred.

2. Quality: It is believed that surface runoff from urban areas may be as highly contaminated as sewage, and the trend is toward storage and treatment of large fractions of surface runoff.

Both of these attitudes are a sharp departure from past design and practice. They indicate that the public now considers storm water to be a major environmental concern.

A great deal of knowledge is lacking, however, particularly about the quality of storm runoff. That the problem is serious is well known and relatively accepted, but it has not been well quantified. No one really understands the specific polluting mechanisms in storm water well enough to be able to analyze the problem by standard engineering methods. It is very much still a research area.

Progress to date has been substantial in only a few cities, and even in the more forward-thinking places the work is embryonic. Significant storm water abatement programs have been undertaken or are planned in Seattle, San Francisco, Chicago and Minneapolis. Other communities have begun special programs dealing with certain local problems. In general, the emphasis to date has been on cleanup of industrial and municipal sewage discharges. It is the success achieved in these fields which has highlighted the severity of the storm water problem. In many communities, industrial and municipal discharges have been curbed or eliminated, yet high levels of pollution continue. Recognition of the fact that these are attributable to storm water in many instances was the first step toward what will be, hopefully, a viable abatement program.

Two current programs are worth noting. The 208 Planning Program (Area-wide Wastewater Management) emphasizes nonpoint pollution as a key element. It supplies state and regional agencies with funds for both analysis and field programs. The program is just getting well underway nationwide, under the guidance of EPA. It will consume more than $200 million in the planning stage alone and should be a big boost to both understanding and implementation.

A second meritorious effort is the Flood Insurance Program. This program is not specifically a "storm water" program, but is directed at alleviating the burden on landowners in the flood plain areas. It is a large multi-million dollar program, however, and it is causing many hydrologic studies to be performed in areas that might not be touched otherwise. The results will be of considerable benefit in avoiding storm water problems in the future.

## 2.9 Research

Many research programs are being conducted on storm water, although in all but a few instances the work is not called research. The word itself has fallen into disfavour because it connotes an ivory tower, and many public officials are seeking action programs. Many action programs find problems which cannot be solved with present knowledge, and some effort is diverted to pursuit of the requisite knowledge. This activity, regardless of its label, is research.

There are four principal areas in which research is being conducted, which relate directly to the storm water problem:

a) quality of surface runoff;

b) analytic methods;

c) treatment processes; and,

e) economics.

Hard data are very sparse on the quality of urban runoff. The most interest has been expressed by EPA, which has supplied funds in this area for seven years or more, at a very modest level. Through its 208 Planning, a many-fold increase in funding is taking place, and the next two years will see large blocks of data on surface runoff quality. Hopefully, there will be a commensurate degree of effort applied to making sense of the data.

Analytic methods, primarily in the form of mathematical models, have been the focus of considerable research in the past five years. These efforts have been supported by EPA, the Corps and a number of states, cities and even private sources. The result has been a large increase in proficiency, both in the models available and in the readiness of users to accept the results. Work in this area is continuing, perhaps at a lesser level than in the past. The emphasis seems to be on a few select problems - real time control models, systems models (models which include other components than storm water) and treatment/economics models. Related research on receiving water quality, particularly the modeling of aquatic ecosystems, is on the rise, and these efforts could be said to be in the storm water area.

The demand for treatment of storm water has raised some fundamental questions. After all, conventional sewage treatment plants were not designed for large, intermittent loads, nor were they prepared for the variable quality often associated with storm water. Several substantial projects have been directed at treatment processes and devices which can cope with these kinds of waste loads. In addition, a good deal of research has been given over to general development of more effective and efficient treatment methods. These activities are continuing in federal and local projects and in the universities.

Economics is, of course, a topic which cuts across all others. Engineers and economists often think differently and may have trouble communicating with one another, yet this is an area of great importance. Estimates of the costs of storm water pollution abatement are in the hundreds of billions of dollars, and extensive efforts are being made to reduce costs. Again, these occur at all levels of government, in the universities and in industry. It is apparent, however, that the economics of storm water protection is very complex. For quality improvement, the goals are being established and the solutions adopted will be the most cost effective. For flood control and storm drainage pollution, however, it is necessary to develop a comprehensive relationship between rainfall intensities, runoff quantities, sewer system capacities, storage and/or retention potential and flood damage costs for varying capacities, and there is, as yet, no comprehensive understanding of the interdependability of these factors.

## 2.10 Bibliography

There is a considerable number of publications available which chronicle the state of storm water management in the United States. These have been published by the American Society of Civil Engineers, as part of its Urban Water Resources Research Program, the American Public Works Association, and the Environmental Protection Agency itself.

It is felt that there would be little purpose in publishing a bibliography of relevant papers, which would be prodigious in length and would merely repeat what has been painstakingly assembled in Section XVI of the EPA publication "Urban Storm Water Management and Technology: an Assessment" dated May, 1974, prepared by the National Environmental Research Center, Office of Research and Development [1].

## 3. SWEDEN

### 3.1 Governmental Structure

Political power rests with the cabinet and the party or parties it represents. The ministers are usually representatives of the political party or parties in power, although, at times, independent experts are called in to serve in the cabinet. The Ministries are small units consisting of no more than 100 persons. They are concerned with the preparation of bills to parliament on budget appropriation, laws, regulations and general rules for the administrative agencies, international relations and higher appointments in the administration. The Ministries are not concerned with details of administration. The cabinet as a whole, is responsible for all governmental decisions reflecting the principle of collective responsibility.

The carrying out of government decisions is entrusted to a number of central administrative agencies each headed by a director-general appointed for a period of six years. The administrative agencies are under obligation to cooperate with each other and are expected to submit proposals to the government outlining the policies they wish to follow. On the basis of their practical experience, they often submit amendments to laws and regulations for consideration by parliament.

The country is divided into a regional organization composed of 24 counties and 270 municipalities.

The National Administration in each of the counties is represented by a governor and the County Administrator. The governors are appointed by government for a six-year term. The provision of health care, hospital services and certain educational vocational training is provided by a County Council which is composed of the municipalities of each council. These County Councils are entitled to impose an income tax to cover their expenses.

The local municipalities each have an elected assembly and their powers are concerned with the provision of housing and associated services, education, public assistance and child welfare. They have the right to levy income tax and they receive revenue of a modest tax on

real estate. They are able to charge for certain services and can decide to supply certain additional public services at their own discretion. They are, nevertheless, required by law to provide a number of basic services for which national subsidies are received.

## 3.2 Background

The hydroelectric power expansion at the beginning of the twentieth century gave rise to legislation to control all construction associated with water. The Water Law passed in 1919-21 controls the construction of hydroelectric structures, bridges and works in navigable waters. It also deals with water supply and the flow of sewerage into lakes and rivers. In 1955, a further law was passed which required the municipalities to arrange for water supply and waste disposal to prevent sanitary discomfort. The county authority can order the municipalities to take appropriate action if the risk of pollution is considered possible. The above laws have put the main responsibility for sanitary and storm sewerage directly on the municipalities and industries responsible for pollution. Where the pollution has been severe, jointly financed Conservation Authorities have been formed in order that it may be economically improved.

## 3.3 Authorities

### 3.3.1 Main regulatory authority

On July 1, 1969, the Environmental Protection Law was passed and this, together with various amendments issued to clarify the regulations, forms the basis of Swedish environmental practice today [2, 3, 4].

The law is designed to protect the environment against pollution from private or public use of properties. It requires that any changes to premises, or the disposal of certain types of sewage, receive the approval of the Franchise Board for the Protection of the Environment (FBPE). The enforcement of the Environmental Law is the responsibility of the National Swedish Environmental Protection Board (N.S.E.P.B.), which is a branch of the National Department of Agriculture.

The Law deals specifically with the flow of wastewater through pipes and with the discharge of effluent from treatment plants and, although

storm runoff, roof and foundation, do not require FBPE permission, the water is now being given special attention.

Since 1969, the following environmentally relevant laws have also been passed:

1. The Public Cleansing Act

2. The National Physical Planning and Land Use Act

3. The Products Hazardous to Man and To The Environment Act

### 3.3.2 Subsidiary authorities

Under the terms of the 1919 Water Law, six Water Courts were established with the purpose of granting approvals to applications that would vary the level of flow of water in a stream.

The distribution of federal grants for water supply and sewerage systems is handled by the Royal Road and Water Construction Authority which is a subdivision of the Federal Department of Communications and Transport.

At the county level the environmental liabilities are limited to certain categorized functions set out in the 1969 Environmental Protection Law. It is anticipated that these responsibilities will be increased in the course of time.

The provision of water and sewerage service within the municipalities is the responsibility of the individual departments and these have formed the Swedish Association of Water and Sewerage Departments, commonly called VAV, which organizes cooperation between the departments in the technical, economical and administrative fields.

## 3.4 Financial Considerations

The federal grant system for sewage works relates the amount of grant to the degree of treatment as illustrated in Table 2. If unemployment is also a factor, the grant may be as high as 75%.

The grants are applicable to new plants, or changes to existing plants and the maximum amount, subject to certain limitations in assessing the cost, is 5 million Swedish crowns ($200,000.). No grant is payable for the sewers leading to the plant unless they have been lengthened in order that the treatment plant might be more favourably located. Such grants are also made available to industries.

TABLE 2. FEDERAL GRANTS TO SEWAGE PLANTS, SWEDEN

| BOD Removal (%) \ Phosphorus Removal (%) | <50 | 50-89 | ≥90 |
|---|---|---|---|
| 60-74 | 30 | 35 | 40 |
| 75-89 | 30 | 35 | 45 |
| ≥90 | 35 | 40 | 50 |

In order to finance the remaining cost of the treatment plants, the municipalities have to arrange their own financing through loans and debentures which are available at favourable interest rates. The charges made to consumers include the cost of the sewage treatment and are computed on the cost of water supplied.

## 3.5 Standards

The N.S.E.P.B. and its provincial counterpart, according to an interpretation of the law, give advice and directions to industries, municipalities and others when there is a potential danger to the environment. A number of reports and guidelines have been published. The most relevant one on this subject has been prepared by one of the Commissions and is entitled, "Forslag Till Dagvattenanvisningar", (Suggestion for Storm Water Directives) [5]. This document represents the general thinking in Sweden at the present time and has an excellent list of references to European and North American literature. Included in the report are sections dealing with general directives, physical sizing of sewerage systems, design and operation of combined and separate systems, snow removal and street flushing, and costs. Several comparisons are also made with results obtained in other foreign countries.

The VAV publishes standards and suggested practices for sewerage system design, construction, testing and operation. These are extensively used by member municipalities and others. They presently have two working committees of interest. One is establishing design standards for water and sewer lines which, it is felt, should lead to a reduction of con-

struction and maintenance costs. The other is, among other things, studying the maintenance of overflow pipes and streams.

A third publisher is Byggandets Samordning (Association for Construction Coordination) which, in its publication "Mark-AMA" [6] has summarized standard drawings and specifications for most types of sewers, trenches, manholes, appurtenances, etc. Sections of this book are often directly referred to by specification writers in order to standardize, and minimize repetitious work.

## 3.6 Design Practices

### 3.6.1 Sanitary sewers

Almost without exception, new sanitary sewers are designed as gravity systems. Very often, foundation drains discharge into the sanitary sewer, since it is the practice in Sweden to place the sanitary sewers at a much lower elevation than storm sewers. Roof drainage is discharged into the storm sewer. When constructed, all sanitary sewers are inspected and tested for leakage, either with air or water. Some cities located along the coast test for chloride in order to determine if there is salt water infiltration. Older sewers are usually checked by television inspection and flow measurements. If a section of the sewer is in very bad shape, it would be rebuilt. However, it is more common to repair only places where excessive infiltration is found. There have been cases where the sewer has been plastic lined.

Both pressurized sewers and vacuum sewers have been built. The latter are particularly popular in factories and shipyards where relocation of the system is easily accomplished. The suburb of Stockholm called Balingeby has a pressurized system, and a complete report has been made on this system. The main advantage of pressurizing is that it enables the sewer line to follow the terrain, thus minimizing expensive cuts, often in rock. Unfortunately, the construction was poor and the costs high. It was generally felt that, with added experience, many of the problems could have been overcome and the cost reduced. Other sources quoted deposits, pump surges and valves as the main problems, plus general operation being less reliable than gravity systems. The main manufacturer of the vacuum sewer system is the Swedish firm of Gustavsberg.

The maximum capacity of the sewage treatment plants is usually four times the dry weather flow for mechanical treatment and twice the dry weather flow for biological and chemical treatment. This does vary from one city to the next, and one of Sweden's major cities is still only capable of treating the dry weather flow. However, the excess flow is stored until treatment is possible, since the Environmental Protection Law does not allow discharge of sewage after primary treatment only.

### 3.6.2 Storm sewers design and treatment

Presently, the storm frequency most often used is the one-year storm. However, there are cases where two-year storms are used for combined sewers and the one-year storm is used for the design of separate systems. For damage-susceptible structures, such as traffic tunnels, the design storm is usually of a longer return period. In the suggestions for a new code [5], now available in draft form, recommendations are made for a one to ten-year storm frequency depending on the area, type and usage. The duration is usually taken as equal to the time of concentration, but the minimum is usually set at ten minutes.

The design storm is derived from data gathered by the Swedish Meteorological Institute. In the case of at least one city, these data are being reworked and new intensity duration curves established. The distribution of the rainfall within a given area is presently under study, since proper information is considered lacking. Another field where the researchers are not satisfied with current data is for short duration rainfall. The design of new storm sewer systems is based only on quantity, with the exception of Stockholm, where quality is being considered in at least one case where the discharge will be made into an exceptionally sensitive recipient. While most cities in Sweden are not taking any action to improve runoff quality, the major cities have investigated the quality of storm runoff and the concept of first flush pollution is firmly established.

Although snow melt is not considered in sizing sewers, a rule of thumb in one handbook states that the snow accumulated during the winter season shall be assumed to run off in fourteen days. However, for most areas the summer rains govern.

New storm sewer systems are being designed with gravity flow in separate systems. But, as in other countries, the older cities have a large percentage of combined sewers and related overflows.

The treatment of storm sewage is currently under study, although no special measures are now required. The treatment possibilities consist of screening, straining, sedimentation, and/or disinfection. A pilot micro-straining plant has been abandoned, since, while the quality was satisfactory, the operational difficulties after rainfall were considerable.

### 3.6.3 Storm runoff attenuation and detention systems

To date, there have been no serious attempts to reduce the rate of storm runoff. However, this possibility has recently been considered, primarily because of the need to raise groundwater levels. This need is due to both urbanization, and the rising of the land which is taking place in Scandinavia, because of decreased glacial pressure. A number of research projects, both laboratory and full scale field studies, are presently underway.

Little use has been made of potential storage on roofs, streets, sidewalks and parks. Past insurance practices, which would not assume responsibility for storm water flooding, may have contributed to this attitude.

The only mandatory measures to restrict storm runoff require that large new developments may not proceed until adequate means are prepared to deal with drainage and to maintain groundwater levels.

Of seventy-seven municipalities in Sweden, only eleven have storm holding tanks. The sizes of these range from 140 to 180,000 cubic metres. In addition to storm holding tanks, the use of storage tunnels seems to be gaining favour [8]. Part of the reason for this is the trend toward a few large treatment plants instead of several small ones, which has resulted in the construction of large trunk collector tunnels. No provisions are being made to treat the contents of storm holding tanks; quite to the contrary, attempts are being made to avoid sedimentation in tanks and sewers wherever possible. However, both storm holding tanks and rock tunnels are ventilated. In addition to the storm

holding tanks and tunnels, parallel pipe packages have also been constructed. At the present time no design standards are available for these detention systems, and the trend, therefore, is to use either German or Norwegian design criteria [9]. The prime factor in limiting the detention period in storm holding tanks is usually construction costs [10]. When the German standards are followed, experience has shown that flooding rarely occurs.

The main criteria considered in locating storm water storage structures are hydraulics, health and public acceptance, land availability and/or sewer system capacity. It is considered important that maintenance occur at least once a year to remove sludge that has settled to the bottom of the tanks.

Although not extensively used before, different types of detention systems are now rapidly gaining favour. Apart from the advantage of reducing the storm water overflows, smaller diameter pipes can be used downstream. According to Swedish experience, the required volume falls within the ten to one hundred cubic metres per hectare range (143 to 1430 cu ft/acre).

Detention tanks include "on-line" tanks on flow-through tanks, either with or without an overflow. There are also "off-line" tanks which are filled and later taken back into the system. In all cases the maximum amount of sediment is passed on to the treatment plant.

## 3.7 Quality

In 1969, the National Swedish Nature Conservancy Office issued tentative standards for all surface waters [11]. These established criteria for potable, recreational, and conservation use and, after a proving period, will be adopted as an official standard [12].

The majority of surface waters in Sweden have improved considerably in the last ten years as the number of treatment plants has increased dramatically. The percentage of municipalities without sewage treatment has decreased from 32% to 4% during this period [13]. Despite this, many lakes have experienced decreased pH values, and this is attributed to industrial air pollution originating outside the country [15].

The improvement in sanitary sewage treatment has enabled attention to be focused on the quality of storm water. Investigations

in Stockholm and Goteborg identified higher than permissible concentrations of phosphates, BOD, lead and other heavy metals and de-icing agents in storm water and, in 1974, gave rise to the formation of a working group to report on the character and properties of urban storm waters in Sweden [14,16]. The working group considered the following questions:

1) What impurity concentrations may be expected in storm water from different urban areas?

2) How do these concentrations vary?

3) What load of impurities are transported by storm water per year, compared to biologically and chemically treated sanitary wastewater?

4) What properties of storm water influence treatment?

The conclusions drawn were:

a) Large storm water discharges give high impurity concentrations.

b) Long duration discharges give lower impurity concentrations.

c) Storm water transports more suspended solids and less phosphorus and nitrogen than sanitary sewage.

d) Despite the findings of the investigations, it was considered that too little is known about the magnitude and causes of storm water pollution.

In designing new sewerage systems, consideration is commonly given to the anticipated pollutional content of the storm water and this leads to treatment of the storm water in some cases.

The advantages of both combined and separate systems were reviewed at a Scandinavian Symposium in 1972 [17]. The following conclusions were drawn:

1) The separate systems' main advantage lies in the ease with which sanitary sewage can be given a high degree of treatment.

2) In order to limit storm water pollution, treatment is required. This can be most conveniently provided at the sanitary treatment facility even if the two sewerage collection systems are separated. However, connections should allow for future separate treatment facilities.

3) The combined system is more economical to construct but the difference in cost is reduced if consideration is given to devices which would limit damage from flooding.

## 3.8 Cleaning Practices

The cleaning practices for streets and sewers, including snow removal and de-icing, vary throughout Sweden from one community to the next. Cleaning is required to take place where a town plan has been established and, in addition to this, the Board of Health may have criteria for certain critical areas.

Thus, Stockholm streets are basically cleaned once per week, while in the business sections the frequency is as high as five times per week. Stockholm also has a boat equipped for keeping its waterfront clean. Goteborg sweeps its main business sections once per week and other urban areas within the city are swept only once or twice a month. The tendency is to use mechanical sweeping rather than flushing, since it has been established that flushing increases pollutants reaching the sewerage systems and their recipients.

Catch basins are cleaned once or twice a year. This is especially warranted in areas where sand is used at the end of winter or early spring. Although not the rule, high pressure flushing of sewers exists in, for example, Malmo where 5% of the system is flushed each month and most of the rest of the system, once per year.

De-icing methods vary depending on how far north the community is located. Stockholm, which receives about 1 metre of snow per season has the following practice: pure salt is used if the temperature is around the freezing point; from the freezing point and down to $-6^{\circ}$ to $-8^{\circ}C$, chloride of soda is used; and, in the range from $-8^{\circ}$ to $-15^{\circ}C$, chloride of potash is used. Cities in southern Sweden use pure salt since this has the least affect in the treatment plants. Melting of snow

is particularly popular in suburban shopping areas where centralized heating systems are used and the haulage distances to a dumping site are often long. Otherwise, most of the snow cleared off the streets in Stockholm goes to one of its 17 sea dumping sites. At these, ice-breaking is often necessary for dispersal of the snow. In "Suggestion for Storm Water Directives" [5], some recommendations are made as to the disposal of snow. Where melting machines are used, separate systems are recommended, with the water going into the storm sewer, providing it does not discharge into a poor recipient. If the melted water is discharged into a combined sewer, this should be done so that overflows are avoided. If the snow is dumped on land, the site should be cleaned at the end of the season. Special consideration in locating the dump should also be made regarding smell and the danger it presents to playing children. A necessary requirement may be fencing [18, 19].

## 3.9 Overflow Design

The great increase in treatment at sewage plants in recent years has caused the pollution from storm water overflows to become a relatively large part of the total pollution load. Measurements taken at seven cities indicated that the overflows contribute 10 to 15% of the annual pollution load. In assessing the possible effects from shock discharges and to determine design criteria, the following parameters are used as typical of overflows:

| Parameter | Unit | Normal Value |
|---|---|---|
| Total Solids | $g/m^3$ | 800 |
| Suspended Solids | " | 300 |
| Volatile Solids | " | 150 |
| $BOD_7$ | " | 80 |
| Total phosphorus | " | 3 |
| Total nitrogen | " | 10 |
| Total coliform | No/100 ml | $10^7$ |
| Thermostable coliform | " | $10^6$ |

The National Swedish Nature Conservancy has issued a storm water directive which proposes that all combined sewer networks should be recon-

structed as separate systems and recommends that the overflows from the systems should be treated, and that in preparing the plans for the system, arrangements should be made for an interim solution, with no discharge under the interim conditions without a minimum of four times dry weather flow dilution.

Almost without exception static regulators are used for combined sewer overflows in the form of manually adjusted weirs. However, in addition, storage in sewers is being developed using either an inflatable weir or a fixed spiral weir which has been invented in Sweden.

In 1968 it was estimated that it would cost 1.6 billion dollars to convert the whole country from combined systems to separate systems. For an eight thousand hectare area in Stockholm, it was estimated that the conversion would cost $116 million dollars, with a further $116 million dollars for service connections and internal building changes [20].

## 3.10 Benefits Achieved

The massive construction of sewage treatment plants has considerably improved water quality. In addition, the thorough cleaning practices for streets have resulted in a less polluted runoff. Swimming beaches within the Stockholm city limits are now open for bathing, having been closed for many years. However, the improvement in storm water quality has been given attention only in the last few years and it is, perhaps, too early to measure the benefit achieved from the improvements planned.

## 3.11 Research

It would appear that there has been considerable criticism in the past that research was not applied and that it lacked any practical purpose. This has given rise to a coordination of research in Scandinavia through Nordforsk, with its Secretariat of Environmental Sciences located in Helsinki, Finland. There are three financing organizations for research in the water and sewerage field in Sweden. These are:

The Swedish Council of Building Research (BVR) responsible for sewers, pipelines and related problems.

The National Swedish Environmental Protection Board (SMV) responsible for receiving waters and the quality of treated water and sludge.

The Administration for Technical Developments (STU) with its responsibility for treatment and processes.

A listing of research projects dealing with storm runoff and overflows is given in Table 3, as abstracted from the VAV Journal [21]. It will be seen from the list that regular interest has been expressed in groundwater and related fields, and that a special program group for hydrogeological research has been established to coordinate and stimulate research efforts in this field. This group has established a research program which is outlined in Table 4, and which has primarily three aims:

1) to produce hydrogeological bases for decision makers in the building process;
2) to study the control and governing of hydrogeological processes; and,
3) to design systems for the management of storm water.

The research work is being undertaken by universities, consultants and contractors, and a special effort is being made to maintain the closest possible contact between the researchers and the practicing engineers [22].

It was only possible to visit one of the constituent research groups, at Chalmers University at Goteborg, where several faculties are coordinating on the program. One group, under Mr. Arnell, [23,24,25,26] is working on the subject of urban runoff using a 0.7 square kilometre area in Goteborg, where the rainfall soil moisture and discharges are being measured. From these measurements, plus an aerial study of rainfall distribution from 13 rain gauges, it is hoped to develop a new design storm hydrograph for Goteborg.

A second group under Mr. Sjoberg is working on a study of flow in sewers and planning to develop a program which will produce a complete hydraulic analysis model, taking into account backwater effects, surges, junction and drop losses. The model uses an implicit solution and differentiates between supercritical and subcritical flows. It was anticipated that it would be completely developed by mid 1975.

A third group led by Mr. Malmquist and Mr. G. Svenson are looking at the composition of storm water [15, 16]. One of their conclusions is that approximately 70% of the heavy metals, suspended matter and oxygen demand in storm water occurs during the first 50% of the storm runoff.

TABLE 3. CURRENT RESEARCH IN SWEDEN.

| Project | Requested By | Amount in Swedish Crowns |
|---|---|---|
| Analysis of systems for storm runoff collection and disposal | V.B.B.<br>L.E. Jansson | 95,000 |
| Literature study. Infiltration of storm water | K.T.H.<br>B. Hultman | 25,000 |
| Disposal of storm runoff. Models for unstable water flow | C.T.H.<br>L. Rohm | 61,000 |
| Follow-up and report of storm water literature | K.T.H.<br>B. Hultman | 13,000 |
| Hydrological model. Effect of pipe trenches on groundwater | Orrje & Co.<br>B. Carlstedt | 39,000 |
| Physical model for an urbanized catchment area | L.T.H.<br>G. Lindh | 88,000 |
| The effect of urbanization on storm runoff and groundwater formation | C.T.H.<br>K. Cederwell | 323,000 |
| Storm water studies for Goteborg | C.T.H.<br>L. Rohm | 106,000 |
| Pollution model for storm runoff | K.T.H.<br>B. Hultman | 24,000 |
| Storm water composition and its variations | C.T.H.<br>T. Hedberg | 7,000 |
| Storm water disposal in a new way. Second Stage | B.P.A, Orrje & Co.<br>K. Paus, B. Carlstedt | 46,000 |
| Full scale tests with storm runoff infiltration, Osteraker | V.B.B.<br>L. Samuelsson | 13,000 |
| Full scale tests with storm runoff infiltration, Harnosand | V.B.B.<br>U. Kihlbon | 25,000 |
| Groundwater formation and variation | C.T.H.<br>P. Wedel | 102,000 |
| Surface water influence on runoff and groundwater formation in an urban area | C.T.H.<br>S. Hansba | 33,000 |
| Studies regarding infiltration of storm runoff into sanitary sewers | Allmane Ingenjorsbyran<br>G. Petersen | 30,000 |
| | | 1,030,000 |
| | | ($240,000) |

TABLE 4. HYDROGEOLOGICAL GROUP RESEARCH PROGRAM, SWEDEN.

| RESEARCH | AIMS |
|---|---|
| Methods & recommendations for investigations and analyses | |
| Identification of infiltration zones & highly permeable strata. | |
| Water flow passages in soil & rock. | |
| Compressibility, permeability & pre-consolidation pressure in soils of low permeability. | |
| Design of hydrogeological models | |
| Momentary pore pressure changes in soil & rock caused by various activities. | Aim 1 |
| Changes in pore pressure in soils of low permeability as a result of changes in pore pressure in adjacent strata of high permeability. | Hydrogeological bases for decision makers in the building process |
| Production of hydrogeological maps & specifications | |
| Systematic documentation of hydrogeological properties & processes caused by various activities. | |
| Methods for construction of impervious tunnels, pipes, etc. | |
| Criteria for assessment of seal requirments. | Aim 2 |
| Methods for grouting & tunnel constructions. | Control and governing of the hydrogeological processes |
| Prevention of groundwater leakage into pipes, backfilled pipe trenches & deep excavations. | |
| Methods for controlled infiltration to rise pore water pressure | |
| Deep infiltration: subterranean erosion, design of infiltration wells. | |
| Surface infiltration: provision of permeable ground areas to compensate for lost natural infiltration areas. | |
| Effect of infiltrating water on the soil & groundwater. | |
| Construction of hydrological runoff models | |
| Runoff processes from different types of areas affected by urbanization. | Aim 3 |
| Dimensioning of pipes | Design of systems for management of storm water |
| Analysis of systems for storm water drainage. | |
| Measurement of flows in pipes. | |
| Feasible dimensions of pipes with reference to installation & costs. | |
| Methods for storm water infiltration & design of retention basins | |
| Design of infiltration basins and retention basins. | |
| Composition of storm water & its treatment. | |

The fourth group at the university, headed by Mr. Joransson and Mr. A. Bjorkmann, is examining the dilution of storm water in receiving waters, with a view to using the quality of the receiving stream as the prime parameter in designing the storm water and combined sewer overflows.

### 3.12 A Brief Review of Storm Water Problems in Norway

As a result of the Environmental Protection Law passed in 1972, the Norwegian Environmental Agency has found it necessary to decentralize. A separate office within each Province deals with approvals and supervision of environmental work. Compared to Sweden, Norway has very few treatment plants and of its sewer systems, nearly 70% are combined. However, the basic idea is for a gradual conversion to separate systems. Unlike Sweden, Oslo places storm water sewers deeper than the sanitary line, which prevents the entry of storm water into the sanitary sewer, but it has been found in older districts that 10 to 15% of the sanitary sewage enters the storm water.

The main receiving water is the Oslo Fjord, which has been under constant study since the University of Oslo began tests early in the 20th century [30]. It has been recommended that the Norwegian Institute for Water Research set up direct research and advise the municipalities around the fjord of the remedial measures which are necessary to continually improve the quality of the water. A storm water simulation model has been developed and used by some of the municipalities. Quality criteria have been introduced, but have only taken into account organic content. In addition, a treatment plant model has been developed, but at the present time no work has been done to develop a receiving water model.

The results to date suggest that combined systems may be superior to separate systems and have justified a continued study into the operation of combined systems. Interesting results are that too large a storage capacity within the sewer may increase the BOD and create high BOD deposits within the pipe.

A paper by Mr. O. Lindholm entitled "A Pollutional Analysis of the Combined Sewer System" [28], reports upon a study using mathematical models for sewer networks and wastewater treatment plants served in a hypothetical catchment by a combined sewer system and plant. The research

has examined the influence of BOD, of groundwater infiltration, of population density, of the influence of retention tanks and the size of secondary clarifiers relative to the optimum setting of storm overflows. It has included a sensitivity analysis, and a study of the effect of transferring storm runoff to the sanitary sewage pipes, comparisons between a combined sewer system and a separate sewer system have been made.

## 4. FRANCE

### 4.1 Governmental Structure

In France, the Central Government is the only body that can pass legislation, and, in the case of laws governing water quality and use, which embraces sewerage and pollution control, several different ministries take part in drafting the legislation.

The Ministry of the Interior is involved in any piece of legislation, and also has the basic responsibility for enforcing adherence to the law when it is passed.

The Ministry of the Quality of Life, through the Secretary of State for the Environment, which in turn works through the National Committee for Water which controls the six Water Basin Authorities, is concerned with all aspects of water management and pollution control.

In urban areas, the local offices of the Ministry of Equipment install, operate and maintain trunk collector systems and treatment plants, while similar services are carried out in rural areas by the Ministry of Agriculture.

The six Water Basin Authorities came into being when the law for "The Regulation and Distribution of Water and the Fight Against Pollution" [32] was passed on December 16, 1964, and broke with tradition in that the six administrative bodies were outside the "common law", and were to be governed by committees composed of equal representation from:

local municipalities;
water users; and,
Central Government.

The geographic limits of the six Authorities followed almost exactly the hydrographic basins of four of the great rivers of France - the Seine, the Loire, the Rhone and the Garonne - plus the French portion of that of the Rhine-Meuse system, and the smaller basins of the rivers in the northern part of the country called Artois-Picardie.

These six Water Basin Authorities are invested with a financial autonomy, and exercise an executive role in the overall picture of water usage. Their terms of reference include carrying out water resource studies, either in-house or by contributing necessary funds to other organizations,

protection of the water from pollution and assisting financially with the installation of works necessary for improving the water in each basin. To meet their costs and to encourage treatment of polluted water, these Authorities levy charges against all users who:

withdraw water from the resources;
introduce pollutants into the environment;
cause changes in the water regime.

The local offices (Directions Départmentales) of the Ministries of Equipment or Agriculture build and maintain trunk collector systems in urban and rural areas, respectively.

## 4.2 Background

France is a country with quite vast water resources and only certain comparatively small regions are having problems. With the urban and industrial growth experienced in the latter part of the nineteenth century, the necessity of some control was recognized, and in 1898, a law was passed defining the general rules concerning water management and pollution control. Unfortunately, the power to enforce the law was so divided between at least six different Ministries that with various departments in each Ministry involved, each making studies independently, widely disparate solutions to the same problems on the same river were put into practice. During the years following, some pieces of legislation were passed concerning water quality and sewerage, the latter being covered by an interministerial circular (#1333) passed on February 22, 1949 [33].

During the 1960's, following rapid industrial and urban expansion in the postwar period, it became apparent that unless concerted action was taken, the previously considered inexhaustible water resources of the country could become, to all intents and purposes, exhausted.

On December 16, 1964, legislation was passed which unified and reinforced the policies, established the Water Basin Authorities, and put some teeth into the law by levying heavy charges against any persons, businesses or communities contributing to pollution of the water resources, and by making substantial grants for operating costs to groups of communities that installed high efficiency treatment facilities.

Since 1964, vast steps have been taken to improve the quality and the management of the water resources. At the present time, Circular #1333 is under revision and, in the near future, a comprehensive standard for sewerage will be established.

## 4.3 Authorities

### 4.3.1 Main regulatory authority

The only legislative body in France is the Central Government. Laws are voted by the Parliament, with the decree for the application of a particular law being signed by the President of the Republic and the interested Ministers. The latter prepare circulars covering the application of the various laws and decrees.

The various texts are augmented by Departmental sanitary regulations signed by the Prefect of each Department. These regulations are established in accordance with a national code.

### 4.3.2 Subsidiary authorities

The legislation of December 16, 1964, vested the six Water Basin Authorities with certain powers, and these six authorities constitute the subsidiary authorities in France.

## 4.4 Financial Considerations

The present requirements state that the choice of a particular sewage system must be made by considering a number of factors, including costs. Capital cost should be amortized and operating costs taken into account.

For treatment plants, and possibly for inter-community trunk sewers, grants of up to 40% plus interest-free loans of up to 10% are available to groups of communities that combine to install such works. These grants, combined with increasing yearly assessments for dumping pollutants in the water courses, make it very attractive for communities to join together to build efficient sewage treatment plants.

At the present time, however, and in the foreseeable future, funds are not available for the treatment of storm water, whether it is an overflow from a combined system or a direct discharge from a separate

system. The highest priority is being given to the construction of treatment plants for sewage, and storm water treatment is low on the list of priorities.

### 4.5 Standards

The standard presently on the statute books for sewerage is Circular #1333 of February 22, 1949. The document is considered very much out of date, and is in the process of being completely revised. The revisions are expected to be passed through the legislature during the next few months.

There is no definite doctrine as to whether sewerage systems should be combined or separate, but in point of fact, most new towns are designed with separate systems, while extensions to older communities are usually combined. However, there are many examples available of both separate and combined systems existing within one locality.

### 4.6 Design Practices

#### 4.6.1 Sanitary sewers

New sanitary systems are designed as gravity sewers with siphons and lift stations installed as necessary.

In a completely separate system, the sanitary sewer accepts only household sanitary wastes, wash water and industrial process waste, with or without pretreatment, while the storm sewer receives the surface and subsoil drainage, street washings and nonpolluted industrial cooling water. In certain very specific instances, some surface drainage may be directed to the sanitary sewers, i.e. in an area where the rain water may pass through stock-piled material and pick up undesirable chemicals.

In areas where the combined system is used, all waters enter the one sewer except where soak-aways are used to recharge the groundwater - mostly in semi-rural areas.

The capacity of sewage treatment plants treating flows from combined sewer systems is between three and five times the mean dry weather flow. Holding tanks are not normally installed downstream from the overflow weirs, and no treatment of the overflow is carried out.

### 4.6.2 Storm sewers and treatment

Storm sewers are also designed as free flow gravity systems and a 10-year storm of 10 to 15 minute duration is used as the criterion for calculating the sizes required.

Runoff quantity is calculated according to the formula derived from research by M. Caquot.

$$Q = 1340\ I^{0.30}\ C^{1.17}\ A^{0.75}$$

where Q = quantity in litres per second

A = the catchment area

C = coefficient of runoff (average)

I = Average slope of catchment area

Up to the present time, runoff quality has not been taken into account when designing new systems. Treatment of storm water is not anticipated. Retention tanks are used in some areas to reduce the direct flow into the receiving waters.

### 4.6.3 Storm runoff attenuation and detention systems

Two systems are used to attenuate storm runoff when such attenuation is considered essential for the protection of the receiving waters. The attenuation is purely to protect receiving waters with inadequate hydraulic capacity.

The most general system is the construction of below grade retention tanks in built-up areas or open ponds in rural areas to permit a regulated discharge to the receiving waters. A second system of in-system storage, by diverting the flows within the sewer network, is in operation in at least one area in the Paris region. The information on flows is telemetred to a central control room from which the diverting mechanisms are operated by remote control. This particular system is very effective due to the physical interconnection in the sewer network, and to the nature of the storms in that area, which tend to be localized concentrated storms travelling in an east-west direction, while the sewer network generally drops in a westerly or southwesterly direction.

## 4.7 Quality

The quality of storm water is not taken into consideration except under exceptional circumstances where a very definite high degree of pollution can be pinpointed, and then the drainage of that particular area is connected to the sanitary sewer.

Certain people deeply involved in pollution control are, however, very cognizant of the problem of the quality of storm water. They are also aware that, at least in certain places, some treatment of the discharges will probably have to be carried out where the receiving waters are highly susceptible to deterioration.

## 4.8 Cleaning Practices

Street working and/or sweeping is essentially a municipal problem, and it is generally left to the Works Department to decide upon the frequency which, in practice, varies widely from once a day to once a week in urban areas. The equipment used varies from hand brushes to water tankers, depending upon the locality.

Snow is not considered a major problem and snow melt is not considered in designing sewers. Generally, the snow is ploughed to the side and allowed to melt. If it should interfere with traffic, in built-up areas, it may be hauled away and dumped into a river, lake or snow dump.

Cleaning programs for sewers vary from locality to locality. In some city areas, all sewers are cleaned once a year, and in adjacent semi-rural areas, one-third of the system is cleaned each year. In other areas, the large sewers are regularly inspected by teams of "Egoutiers" who call for cleaning as and when required.

Cleaning is carried out by means of high pressure water jets plus the use of "pigs" in smaller diameter pipes. In most areas, high pressure flushing in dry weather is normal for smaller pipes, but not for larger installations.

Catch basins are usually installed on new networks, depending on the degree to which the area is built up, and these catch basins are normally cleaned at least twice a year, either by hand or by suction pumps. Again, much depends upon the locality.

### 4.9 Overflow Design

There is no fixed policy regarding overflow design, the overflows being considered a means of protecting the sewage treatment plant from damage.

Overflow control is by end or side weirs, although consideration is being given to vortex weirs for future installations. No consideration is given to the quality of the overflow, and weirs are generally set to operate at three to five times the DWF. No work has been done on dynamic weirs.

### 4.10 Benefits Achieved

There is no treatment of storm water and, therefore, there are no benefits. However, the measures taken to ensure the treatment of sanitary sewage and industrial effluent have achieved very great benefits. The increase in pollution of water resources has, in general, been halted and the country can look forward to a decrease in the future. The measures already taken are probably most noticeable to the average person by the increase in salmon and trout in rivers where previously they had disappeared.

### 4.11 Special Considerations

Three separate communities were visited in France: the City of Grenoble; the industrial area to the northeast of Paris, Seine-St. Denis; and a rural area, Val d'Oise, in which is situated the new town of Cergy-Pontoise. Each of these areas has its own particular problems, and is dealing with them in different ways.

Grenoble is located on a low-lying flat plain between the rivers Drac and Isère. In consequence, the water table is close to the surface and deep excavation is a very expensive operation. As a result, the sewers, which are combined in the older parts of the city, are laid to absolute minimum gradients. Storm water is considered to be an asset in flushing the sewer system; however, during the spring, with the catchment areas for the rivers being in the high mountains, both the Drac and the Isère are in spate, and the levels rise above those in large parts of the town causing backups in the sewer system and flooding.

In the "new city" (Olympic Village) very strictly controlled separate systems were installed, and are comparatively free from infiltration problems. Unfortunately, both the sanitary and storm sewers discharge directly into the old combined system, which, in turn, discharges everything into the River Isère without any treatment. At the point of discharge, this river carries large quantities of solids in suspension from upstream areas.

Potable water for the city is drawn from the River Drac, which is comparatively free from suspended solids and other pollutants.

Treatment of the sewage is now being considered, but with the sewer systems presently in operation giving such a high degree of dilution, plus the difficulties with flooding, the solution to the problem is going to be difficult and expensive.

In the industrialized area of Seine-St. Denis in the Paris region, the trunk sewer system comes under the Direction Départementale de l'Equipment. In 1933, zones were established to be furnished with separate or combined systems. The principles used in making this decision are obscure but, in general, new systems in the area are installed as separate systems. A great deal of study has been done concerning the control of storm water discharges, and a small remotely controlled system is in operation which reduces the rate of discharge by making use of the in-system storage capacity of the network. The characteristics of the storms in this area are such that this method of retention works very well. The storms are generally quite concentrated and travel across the area in an easterly direction. It is anticipated that the monitoring and control system will be expanded as the network grows, and will eventually be connected to a computer.

The less industrialized area of the Val d'Oise, in which the trunk sewer network is under the control of the Direction Départementale de l'Agriculture, has been divided into communities of two classifications, urban and rural, according to population density. Throughout this area, most new sewer systems are separate, with storm water discharges into the receiving waters being moderated by use of retention basins, the networks not being sufficiently interconnected to permit economical in-system storage. No treatment of storm water is currently envisaged, but pollution emanating

from storm water discharges has been recognized as being a potential problem in the future.

## 5. UNITED KINGDOM

### 5.1 Governmental Structure

The government of the United Kingdom is a single governing body responsible for parliamentary legislation affecting the entire country. Scotland, Wales and Northern Ireland have local offices responsible for the administration of government, but are without any political body able to legislate for what might be regarded as problems peculiar to each national region. Thus, although there may be minor differences in structure resulting from historical events, the actual relationship between central government and local authority is fundamentally the same for all parts of the country.

Until April 1, 1974, the local government structure comprised councils of elected representatives for counties, county boroughs, boroughs, etc. each with a responsibility for roads, housing, planning, schools, public health, etc. The financial support of the local authorities is derived from taxes assessed on residential, commercial and industrial properties.

In the years preceding April 1, 1974, the water supply industry had been consolidated into 157 authorities, replacing the roughly fourteen hundred that had formerly existed. The responsibility for river flow and quality and catchment management was vested in 29 River Boards. Although sewerage and sewage disposal were the responsibility of the local authorities, geographical necessity occasionally required the formation of a joint sewerage board to operate facilities on behalf of two or more adjacent municipalities. There were 1393 sewerage authorities and sewage disposal boards.

On April 1, 1974, the whole of the local government structure was reorganized and the municipal authorities were regrouped into larger regional authorities. At the same time, under the terms of the Water Act, 1973 [34], the water, sewerage, sewage disposal and river board authorities were themselves reformed into ten Regional Water Authorities. Thus, at one and the same time, the responsibility for virtually every municipal service passed to another authority. The only exceptions to this change appear to have been the private water companies and the

responsibilities for planning, constructing, and maintaining sewers, which remained with the local authority but on an agency basis on behalf of the water authorities.

In summary, therefore, the present governmental structure places the responsibility for water supply, water conservation, water quality, sewage disposal and all related matters into the hands of ten regional all-purpose river basin authorities in England and Wales.

## 5.2 Historical Background

A brief summary of the historical development of storm and sanitary sewerage in the United Kingdom is contained in Chapter I of the final report of the Technical Committee on Storm Overflows and the Disposal of Storm Sewage [35]. This states that, in the early part of the 19th century, sewers existed for surface water only, and at that time it was illegal to discharge what is now known as sewage into them. Sewage disposal was achieved simply by moving refuse from the immediate vicinity of the dwelling; any nearby water course was regarded as a logical and proper place to dump it. Later, following the introduction of the water closet, domestic sewage was discharged to cesspools and these, in turn, were often connected to surface water sewers which conveyed the cesspool liquid to the watercourse.

The uncontrolled discharge of industrial wastes, as well as sewage, during the industrial revolution caused the rapid deterioration of many rivers and commissions were appointed in 1857, 1865 and 1868 to inquire into various aspects of sewage disposal in towns and the prevention of pollution of rivers. The conclusion reached was that sewage should be collected from individual properties and conveyed to a central point for disposal on land. The sewage farm, which provided settlement and land irrigation, then became the most common mode of disposal.

The Public Health Act, 1875 and the Rivers Pollution Prevention Act, 1876 consolidated the law relating to sewage disposal and river pollution, and under the Act of 1876, it was deemed an offence to discharge sewage to a river.

Developments were taking place meantime in the fields of sewerage and sewage treatment. Sanitary sewage systems were growing out of what, in many cases, were the old surface water systems which had terminated at their various points of discharge to the rivers, and while the sewage farm was the standard method of treatment, the large areas of land needed were becoming more difficult to acquire. This led to a search for forms of treatment requiring less land.

The Royal Commission on Sewage Disposal, appointed in 1898, published a series of reports on the treatment and disposal of sewage. These included recommendations for restricting the quantity of sewage to be treated at one sewage works when the flow was swollen by surface water runoff.

The sanitary sewage systems, which had grown from somewhat haphazard surface water drainage arrangements, were being required to take greater and greater flows of both sanitary sewage and surface water, as populations and the paving of road surfaces increased, and there was a great deal of improvisation to meet the changing circumstances. The complexity of cross connections in many towns can only have resulted from piecemeal attempts to relieve overloaded sewers by diverting some of the flow into others which, at the time, had some spare capacity. It was not thought necessary to convey all the flow to the final point of disposal; the cost of building the necessary sewers would often have been prohibitive and excess flows had to be discharged on the way in such a manner as to avoid flooding. The many outlets that had existed on the old systems provided ready-made facilities for the discharge of the excess flows to the nearest watercourse. These outlets were, in effect, the first storm overflows.

It should be realized that many of the countries largest systems have developed from such beginnings. Although improvements have been made from time to time, by the laying of relief sewers and, in some cases, by excluding surface water from the sanitary sewers, many authorities have not yet succeeded in overcoming the drawbacks stemming from these origins.

Thus, the present day dual purpose sewer developed from a water carrier, which was often a culverted stream into which sanitary

sewage had, over the years, been admitted. Today, they are regarded as sewers carrying sanitary sewage into which surface water is admitted in wet weather.

From the earliest days, it was generally accepted that it would be uneconomical to design entire sewerage systems to carry storm flows to the final point of disposal. It has been the usual practice to relieve the system of some of the excess flow at selected points by providing storm overflows. In the majority of cases, these take the form of a device, such as the weir, for separating the excess flow, which is then discharged to a pipe from the overflow chamber to the nearest watercourse. By this means it is possible to restrict the quantity finally passed for treatment to something very much less than the maximum reaching the sewers in times of rainfall and, consequently, to limit the size of the downstream sewers to reasonable dimensions.

In the latter part of the 19th century, the Local Government Board was the central authority responsible for sewerage and sewage disposal. One of the Board's requirements was that storm overflows should not come into operation until a flow equal to six times the dry weather flow was being conveyed through the sewage works for treatment.

The Royal Commission on Sewage Disposal, which was appointed in 1898, in its fifth report published in 1908, acknowledged that it would be impractical to dispense altogether with storm overflows. However, it recommended that they be used sparingly, and that the river board or, in districts where there was no river board, the county council, should have power to require the local authority to alter any storm overflows which, in their opinion, permitted an excessive amount of unpurified sewage to flow over them.

Another requirement of the Local Government Board was that flows up to three times the normal dry weather flow should be given full treatment, and flows between three and six times the dry weather flow should be given land treatment, or should be passed through storm filters. On this subject the Royal Commission included a recommendation that special standby tanks should be provided at the sewage works and kept empty for the purpose of receiving the excess storm water. The Commission considered that, during storms, the amount of flow which could

be passed through the normal treatment tanks could be increased to about three times the dry weather flow without serious disadvantage. It also considered that any overflow of the works should be made from the stand-by storm water tanks and that overflow should only become effective and operational when the tanks were full.

Although there was no official publication, it is generally believed that the Local Government Board's requirements were modified in accordance with the Royal Commission's recommendations, but the Board appeared to have adhered to its original requirement that, in the absence of any special circumstances, overflow weirs should be fixed so as not to come into operation until the flow exceeded six times the average dry weather flow. When, in 1919, the Ministry of Health took over the functions of the Local Government Board in relation to sewerage and sewage disposal, these requirements, although as far as is known still not laid down in any official document, were included in what became generally known as the Ministry of Health Requirements. Regardless of their obscure origin, they are the standard to which designers have worked in the United Kingdom for many years.

Conditions have changed considerably since these requirements first became the basis of design practice, some 60 years ago. Despite these changes, the old standards are still generally followed. They have been subjected to criticism but no alternative basis of design has been laid down.

Under the Rivers (Prevention of Pollution) Act, 1951, it became necessary to obtain the consent of the appropriate river board before making any new or altering any existing discharge of industrial or sewage effluent to a stream and; in granting consent, the boards were empowered to impose conditions. In issuing consent to a discharge from a storm overflow, it became the practice to stipulate a setting, usually by requiring no discharge to take place until a specified flow was being passed to the sewage works for treatment.

A setting equivalent to six times dry weather flow was, and still is, frequently stipulated in line with the old requirements, but sometimes there have been differences of opinion as to what should constitute a special case, and what should then be the appropriate setting. There was a growing practice among some river boards to ask for overflow

settings of eight or even ten times dry weather flow, but there was no uniformity of practice or knowledge of the magnitude of the benefits that these higher settings would bring about.

## 5.3 Regulatory Authorities

The Secretaries of State for the Environment and for Wales exercise the central government functions relating to control of water pollution. These include power to direct the variation or revocation of a consent to a discharge, to confirm bylaws, to determine appeals, and to act in the event of default by a water authority. Guidance is given by circulars and technical memoranda to the regional authorities on various matters affecting water quality. There is close liaison between the Departments and the regional authorities on both technical and administrative matters. Standing technical committees advise the Secretary of State for the Environment on the effects on rivers of the use of synthetic detergents and related products, and promote and coordinate studies of practical problems related to water quality both generally and in particular catchment areas. Other committees and working parties are appointed to examine special problems as they arise.

The executive responsibility for water rests with the ten regional water authorities. These authorities are the regulatory bodies which ensure compliance with the laws governing the quality of water. The control of pollution of any kind has been rationalized by the Control of Pollution Act, 1974 [36], which has both supplemented and repealed, in part, the very considerable existing legislation dealing with the public health and the maintenance of purity or good quality in the many streams and other waters in the country.

Thus, in the United Kingdom, apart from the rights of individuals and organizations to make full use of the courts to protect the environment, the direct responsibility for the prevention of the pollution of water supplies rests with the same authority that has the responsibility for the operation of sewers, sewage treatment plants, and water supplies. These regional authorities are very extensive and very new, and it is worth remarking that, at the time of our investigation, there were already signs of internal reorganization within some authorities to

rationalize their operation. Each of these authorities is autonomous and the chairman of each is a member of the National Water Council. This council is a coordinating, consulting and advisory body and does not attempt to direct the activities within individual authorities. The undertaking of this investigation so soon after the formation of these authorities made it impossible to observe their functioning. It will, however, be of interest in the future to see how the various authorities undertake the task of policing the maintenance of their own water supplies and, in particular, how the individual authorities, with perhaps ultimately different establishments will be able to both effectively police themselves, as well as maintain a balance between possible conflicting budgetary requirements.

We were informed that, at the present time, there are no established priorities for those works necessary to improve river water quality. It is our understanding that each individual authority would prepare its own budget and that these, in turn, would be centrally coordinated. In this regard, there will, no doubt, be a most effective liaison between the National Water Council and the Directorate General Water Engineering of the Department of the Environment, in order that the relative priorities of alternative requirements may be evaluated.

## 5.4 Standards

The improvement of river water quality has received considerable attention in England and Wales and, although there are no determined standards to which the rivers shall be improved, there has been a most comprehensive river pollution survey, undertaken by the Department of the Environment and the Welsh office with the cooperation of the river authorities. This survey was published in two parts, volume one in 1971 and volume two in 1972 [37]. A further volume published in 1973 [38] updated the 1972 volume.

Volume one consists essentially of an inventory of the river authority areas and the classification of the river mileages within those areas into four classes of chemical pollution: class one, unpolluted, through class four, grossly polluted. It then compares the biological and chemical classifications of tidal and non-tidal rivers and

effects further comparisons by river authority areas. It is complete with a number of maps to scale of 1/4 inch to a mile, identifying the various lengths of classified rivers.

Volume two takes the same river authority areas and summarizes in those areas the discharges of sewage effluent, crude sewage, storm sewage from unsatisfactory storm overflows, industrial effluent, and details of expenditures estimated to be required to remedy the situations. The report includes a brief forecast of the improvement anticipated as a result of the expenditures on remedial works.

The third volume represents an updating of the information contained in the previous volume and contains an account of changes in discharges that have taken place in the intervening period in most of the river authority areas.

Tables 5 and 6 are taken from volume one of this report and compare the mileages of non-tidal and tidal rivers in the 1958 and 1970 reports.

TABLE 5. COMPARISON OF MILEAGES BY CHEMICAL CLASSIFICATION, 1958 AND 1970, NON-TIDAL RIVERS, UNITED KINGDOM

| Chemical Classification | | 1958 (Miles) | 1970 (Miles) | 1970 compared with 1958 (Miles) |
|---|---|---|---|---|
| Class 1 | Unpolluted | 14,603 (72.9%) | 17,000 (76.2%) | +2,397 |
| Class 2 | Doubtful | 2,865 (14.3%) | 3,290 (14.7%) | + 425 |
| Class 3 | Poor | 1,279 ( 6.4%) | 1,071 ( 4.8%) | - 208 |
| Class 4 | Grossly polluted | 1,278 ( 6.4%) | 952 ( 4.3%) | - 326 |
| Total, England and Wales | | 20,025 (100%) | 22,313 (100%) | +2,288 |

TABLE 6. COMPARISON OF MILEAGES BY CHEMICAL CLASSIFICATION, 1958 AND 1970, TIDAL RIVERS, UNITED KINGDOM

| Chemical Classification | 1958 (Miles) | | 1970 (Miles) | | 1970 compared with 1958 (Miles) |
|---|---|---|---|---|---|
| Class 1 | 720 | (40.7%) | 862 | (48.1%) | +142 |
| Class 2 | 580 | (32.8%) | 419 | (23.4%) | -161 |
| Class 3 | 250 | (14.1%) | 301 | (16.8%) | + 51 |
| Class 4 | 220 | (12.4%) | 209 | (11.7%) | - 11 |
| Total, England and Wales | 1,770 | (100%) | 1,791 | (100%) | + 21 |

The report refers to the difference in mileages recorded in both these tables and suggests that this is due to the different criteria adopted for the two surveys and to the greater accuracy required for the later survey. There has been definite improvement in the quality and it is considered in the report that this improvement has been due to the steadily increasing expenditure on sewage and trade effluent treatment, stimulated by the system of control of discharges into rivers described in Appendix 2 of that report (reproduced in Appendix 1 of this report).

It is worth noting here that the full powers of control by river authorities of discharges to non-tidal rivers have applied only since 1963. Improvements in the quality of discharges have been achieved mainly by persuasion and the voluntary cooperation of dischargers, although river authorities could and did prosecute when there was no attempt to meet the conditions attached to consent to discharge. It is apparent that the discharge from storm overflows, while coming under river authority control, was not identified as the highest priority in need of treatment. In chapter 4 of volume two, the discharges of storm sewage from unsatisfactory storm overflows are identified by river authority. It was estimated that there were between 10 and 12 thousand storm overflows in England and Wales, and 2,162 were considered to be unsatisfactory at that time. The authorities were asked what remedial works would be required and the replies are summarized as briefly as possible in Table 7.

TABLE 7. COURSES OF UNSATISFACTORY STORM OVERFLOWS, UNITED KINGDOM

| River Authority | Unsatisfactory Overflows | Comments |
|---|---|---|
| Northumbria | 8 | 1 caused by mining subsidence 2 require resewering at cost in excess of $16 million. |
| Yorkshire | 302 | No details of cost given but 104 occur in areas where remedial works are likely to be particularly costly. |
| Trent | 80 | No details of cost given, but much resewering required. |
| Lincolnshire | 12 | Remedial works will include resewerage and increased treatment plant capacity. |
| Welland & Nene | Nil | |
| Great Ouse | Nil | |
| East Suffolk & Norfolk | 19 | Remedial works are largely resewering. |
| Essex | 29 | Remedial works require larger capacity sanitary sewers and flow separations. |
| Kent | 11 | Remedial works all in hand. |
| Sussex | 5 | Resewering is required in all cases |
| Hampshire | 7 | Most cases would require relief sewers and provision of screens. |
| Isle of Wight | 35 | Remedial works would require relief sewers, screening and provision of adequate sewer capacity with tidal storage. |
| Avon & Dorset | 14 | Remedial works include relief sewers enlarged capacity and separation. |
| Devon | 33 | Most cases require new sewers and some additional treatment capacity. |

| River Authority | Unsatisfactory Overflows | Comments |
|---|---|---|
| Cornwall | 83 | Extensive resewering required with high overall cost. |
| Somerset | 10 | No details available. |
| Bristol Avon | 36 | Some require major resewering, some only improvements at moderate cost. |
| Severn | 123 | Many large schemes of resewering required. Overall costs will be high, but not all attributable to elimination or improvement of overflows. |
| Usk | 176 | In many cases the remedial works will be confined to reconstruction of overflows and adjustment of weirs. Others will be improved as a result of construction of major sewerage works. |
| Glamorgan | 5 | All will be improved or eliminated incidental to major long term sewerage schemes. |
| South West Wales | 23 | Several could be improved at moderate cost, some small works require extension. |
| Gwynedd | 3 | No extensive work required. |
| Dee & Clwyd | 30 | Indications are that extensive resewering is required at high cost. |
| Mersey & Weaver | 791 | A number of overflows could be improved at moderate cost, but if all were to be brought up to satisfactory standard extensive resewering would be required in the built up areas. |
| Lancashire | 268 | The cost of improvement to approximately 160 of the worst overflows is estimated to be in excess of $16 million. |

| River Authority | Unsatisfactory Overflows | Comments |
|---|---|---|
| Cumberland | 20 | Some resewering and some resetting of weirs required. |
| Thames Conservancy | 10 | Mainly requires regional or local resewerage. |
| Lee Conservancy | Nil | |
| Port of London Authority | 25 | It is considered that a major scheme of trunk sewering is required costing $96 million. It is also pointed out that this sum might be spent on sewage treatment with greater benefit. |

It is interesting to note that, of a total of 2,162 unsatisfactory storm overflows, 1,660 or nearly 77% of the unsatisfactory overflows are located in only five of the twenty-nine water authority areas. These, in general, represent the industrial midlands of the United Kingdon.

The Control of Pollution Act 1974 requires that all discharges into relevant waters be made with the official consent of the appropriate Water Authority. For sewage effluent, it has been the requirement since 1912 that it conform to the Royal Commission Standard, that is, 20 ppm BOD and 30 ppm suspends solids. This standard was established on the basis of dilution in the receiving stream with eight volumes of clean river water. Until the formation of the River Boards in 1950-51, little attention was paid to this requirement but it has been more rigorously applied since that time.

In the matter of storm overflows there has been no official consideration of the degree of dilution required, nor is there a quality standard established for the overflow itself.

## 5.5 Design Practices

### 5.5.1 Sanitary sewers

The three types of sewerage systems in the United Kingdom are the combined, the partially separate, and the separate. In the combined,

all the sanitary sewage and all the surface water are carried by the same sewer. In the partially separate system, only a proportion of the surface water, and that usually from back roofs and yards, is discharged to the sanitary sewer and the remainder is collected in the surface water sewers. In the separate system, sanitary sewage and surface water are theoretically kept strictly in separate sewers.

Wherever possible at the present time, new systems are designed as separate and it is only in the resewering of heavily built up areas that either combined or partially separate systems would be constructed. The sewers are always designed as gravity sewers with pressurized sewers being used only as a forcemain when the topography requires that a lift station be constructed to transfer the collected sewage to a gravity system.

The sewers are designed and constructed in general accordance with the British Standard Code of Practice CP2005 [39].

The capacity of the sewer is based on a calculation of the average flow in the sewer based upon existing water supply statistics and an estimate of future changes. This flow, referred to as the dry weather flow, is multiplied by a factor of six to determine the capacity of the sewer to the treatment plant.

The hydraulic formulae used have been those of Barnes, Manning, Crimp and Bruges but it is considered in the code of practice that the Colebrook White formula is now being more widely adopted.

5.5.2 Storm sewers

The problems of storm sewer design are reviewed in the proceedings of a research colloquium held at Bristol University in April, 1973 [40].

There are basically two methods used to derive the flow intensities required for storm sewer design. The first is the rational method, the second is known as the RRL hydrograph method. The rational method assumes that variations in the rate of rainfall during a storm and the volume of water retained in the sewer system may be neglected, and also that the maximum discharge of storm water from an area occurs when the duration of the storm is equal to the time of concentration of that area.

The rate of rainfall used for this calculation was previously the Ministry of Health's formulae, where $R = \frac{30}{t + 10}$ or $R = \frac{40}{t + 20}$, where R is inches per hour rainfall and t is -3.55 duration of storm in minutes. This has been largely superceded by the Bilham formula which was derived in 1935, where $N = 1.25t\ (R + 0.1)$, where N is the number of storms of this intensity in ten years, t = duration in hours and R = total rainfall in inches in the time t.

It has been shown that the rainfall intensities derived from the Bilham formula are not uniformly applicable to the whole of the country, and in recent years there has been considerable research by the meteorological office to evaluate for the British Isles the appropriate rainfall patterns for differing times for differing frequencies of recurrence. The meteorological office will now supply to any design engineer, for any ten kilometre square in the British Isles, the storm intensities which they consider to be appropriate to that location, and it is this storm intensity which would be used for the runoff calculations.

The RRL hydrograph method was developed by the Road Research Laboratory. The method, which is calculated using a computer, first prepares an area and time diagram of the catchment. Then, using a suitable design storm profile, the first approximation to the hydrograph is calculated and this, in effect, gives an inflow curve to a reservoir, the volume of which is equal to the maximum volume occupied by water in the sewer at the time of peak rate of runoff. A calculation is then carried out to determine the outflow curve of this reservoir which is the final hydrograph.

In each case, the storm frequencies are varied, depending upon the location and the type of construction. Heavily built up areas are usually based on a five-year return storm, and lightly developed residential areas on a two-year storm. If an area is subject to exceptional flood damage, then a 20-year return storm would be used. The RRL method is commonly used at the present time and is considered to be more appropriate than some of the more complex computer systems currently available. In a paper presented in April, 1973, Young referred to the program and commented that it is possibly the best available at present. Later, after reviewing various aspects, he stated that the latest information from the meterological office on rainfall profiles could not be used in the method. During the

course of the study, a member of a consulting engineering company, Hepworth, proposed in an article in New Civil Engineer that the Road Research Laboratory method was not the most suitable and could lead to gross errors. In the June, 1973 journal of the Swedish Society of Civil Engineers, Professor Gurner Lind of the University of Lund commented that the RRL method operated satisfactorily only under the following conditions: area less than 12 sq km, impervious area at least 15% of total and uniformly distributed, storm frequency not greater than 20 years.

The formulae used for the hydraulic design of the storm sewers are identical to those used for the sanitary sewers.

### 5.5.3 Overflows

The greatest number of overflows on storm sewers in the United Kingdom are of the weir type, although examples of stilling basins, storage and vortex types have also been constructed.

The weir type is constructed either with a low or high configuration. It is generally acknowledged that the low type is possibly the worst offender in relation to the discharge of foul matter during storm overflows. In consequence, these are the subject of redesign which, in many instances, is difficult due to the restrictive configurations of the overflow structure relative to the surrounding construction.

Work by Dr. Prus Chacinski reported in reference [41] has developed a storm sewage spiral flow separator which, it is considered, can be fitted into almost any configuration of street and which, it is claimed, will improve very considerably, the separation of solids. It is believed that it operates along similar principles to the Helical Bend Combined Sewer Overflow reported upon by the APWA Research Foundation.

The design of storm sewage overflows was reviewed at a symposium held at the Institution of Civil Engineers, London, in 1970 [41] and most design has proceeded in accordance with the findings.

The general rule has been that overflows are provided so that the flow in excess of six times the DWF is removed from the sewer to a receiving stream. Although some River Boards determined in the 1950s that a flow of eight or even ten DWF was a more appropriate flow to be carried in the sewer before overflow, no work had been done to determine the

wisdom of the number or the benefits which would result; thus, it is not a common current design factor. The final report of the Technical Committee on storm overflows [35] considered the custom of expressing the setting of an overflow as a multiple of the dry weather flow to be basically unsatisfactory. They proposed a setting of Q, where Q = the DWF + 300 p + 2e, where DWF is the dry weather flow in gallons per day, p is the population of the upstream area, and e is the volume of industrial effluent in gallons discharged to the sewer in 24 hours.

The committee considered that, of the overflow structures studied, the high side weir and stilling pond preferentially retained gross solids but not to any great extent. The vortex overflow studies had no advantages over the high side weir or the stilling ponds, and the low side weirs were inefficient, particularly in respect to flow control. The committee considered that storm overflows should generally be expected to perform more efficiently when the upstream sewer is laid at a subcritical gradient and that, wherever practical, a form of hydraulic control should be incorporated as a part of the storm overflow installation. This would control to some degree of accuracy the maximum rate of flow passed forward.

The committee undertook a survey of overflows to determine how many were unsatisfactory and the reasons for their unsatisfactory operation. Of the 849 overflows surveyed 370 were classified as unsatisfactory. Table 8 summarizes the reasons for the unsatisfactory classifications.

Although the greatest number of unsatisfactory overflows occurred from the combined influence with neighbouring overflows, category E, it was the opinion of the committee that the main reason why many overflows were unsatisfactory was that the settings were too often below what has for decades been the normal standard, namely six DWF.

### 5.5.4 Storm runoff attenuation and detention systems

From replies to the questionnaires distributed for this study, it would seem that little consideration has been given to storm runoff attenuation, although balancing tanks may be constructed. It appears that there are no mandatory measures to restrict runoff from new developments,

TABLE 8. EFFECTS OF UNSATISFACTORY STORM OVERFLOWS, UNITED KINGDOM

| Effect | | Number of Unsatisfactory Overflows | Percentage Unsatisfactory for each reason |
|---|---|---|---|
| A | Stranding of solids in vicinity of watercourse | 74 | 24 |
| B | Effect on fish, biology | 55 | 17 |
| C | Operation in dry weather | 33 | 10 |
| D | Too frequent operation in wet weather | 131 | 41 |
| E | Combined influence with neighbouring overflows | 149 | 47 |
| F | Deposits of sludge in watercourse | 8 | 3 |
| G | Miscellaneous | 11 | 3 |
| | | 461 | |

with the exception of certain new towns, although some replies suggested that new developments would be opposed by the Regional Water Authorities if adequate drainage facilities did not exist.

On a combined sewage system, storm holding tanks are generally constructed at the sewage treatment plants. The size of the tanks is generally based on storage for two hours of the difference between three DWF and six DWF; this was found in the final report of the Technical Committee to be a satisfactory quantity. If the first tank to fill has no overflow, then the first flush is retained in this tank and would normally be pumped back for treatment when the storm has finished.

At the new town of Stevenage, to the north of London, the discharge of storm overflows is made to the River Lee upstream from the water intake operated by the Metropolitan Water Board for the city of London. The design of the storm drainage system in Stevenage was, therefore, required to cause no deterioration to the quality of the water abstracted for water consumption and further, it was required that the

flow rate discharged to the Lee would not exceed that which it had been in the past. Balancing water meadows have, in consequence, been constructed which retain and attenuate the storm flows and discharge the accumulated waters over a period of up to 20 hours after the end of the storm. A number of these have been constructed, the largest with a capacity of 12 acre feet, and each consists of an earth embankment containing a concrete weir with penstock control. The penstock is used to control the outflow and the weir, and a weir plate is used to control the storage behind the embankment. The maximum capacity is equivalent to a 20 year recurring storm, or without the weir plate, to that of a 10 year recurring storm. All storm water draining from trade premises is required to be passed through oil separation tanks before discharge to the storm sewers. Secondary oil separation tanks are provided on the storm sewers before they reach the balancing water meadows. It has been found that the combination of these tanks and the settlement which occurs in the balancing water meadows has rendered the water discharged downstream to be of a very commendable quality. No complaints have been received from the water authority regarding deterioration of supply.

In paper number 7341 [42] to the Institution of Civil Engineers, March, 1971, Hedley and King referred to work which they undertook in their investigation of storm runoff in a combined system in the Haunch Valley in the City of Birmingham. They summarized their results as follows:

a) The oblique and side weir type of overflow afforded no degree of quality separation.
b) While some relationship could be established between BOD and SS for the DWF, no significant relationship was discovered for storm sewage, suggesting that the major part of the polluting load was carried, either in solution, or in very fine suspension.
c) During storms, a polluting load of considerably greater rate than that resulting from the sewage alone was carried off.
d) The total excess polluting load for both BOD and SS generally increased with the time interval from the previous storm.
e) The rate at which this load was carried off varied considerably from storm to storm, but for intense storms, the whole of the load could be carried off in approximately the time of concentration and at a

fairly uniform rate. It was found that these results were in general accord with those drawn from other investigations and that the public sewers in the Haunch Valley were found to be self-cleansing, even at night. It was, therefore, concluded that it would be reasonable to assume that the most probable sources of this additional pollution would be the roads and other surfaces and debris flushed from individual house connections.

As a result of this work, the authors considered that the performance of even the most efficient storm overflow would be inadequate to meet the future conditions of the water authorities and suggested that there were only three possible solutions to this problem. Firstly, to increase the size of the sewers and take all or a greater proportion of the flow to full treatment; secondly, to effectively separate the system of drainage; and thirdly, to provide some storage device to individual overflows. Both the first and second would require enormous capital expense and the authors considered the third method in depth.

A scheme was subsequently prepared proposing storage units with double weirs, such that the lower weir discharged to storage and the higher weir to the water course. After the storm is over the storage drains back into the sewer and it is reported that the tanks are working precisely as anticipated.

### 5.5.5 Street and sewer cleaning practices

Although the practices vary throughout the country, it would appear on a broad basis that mechanical means of street cleaning are used in most residential and downtown areas with an average frequency of once per week. Sewers are cleaned only when necessary and normally by dragging a scraper through them. High pressure water jets are used for smaller sewers. Catch basins are almost universally installed to prevent the entry of foreign deleterious material and these are cleaned generally by suction.

## 5.6 Quality

Considerable work has been carried out in evaluating the quality of storm sewage, the quality of storm overflows and their effect upon the recipient streams.

Brief abstracts from the referenced literature can do no more than identify the magnitude of the problem.

The final Report of the Technical Committee, Chapter 3, gives the following results of an investigation carried out over a period of five years by the Water Pollution Research Laboratory at the towns of Northampton, Brighouse and Bradford, all located in the Midlands.

| Constituent | Concentration (mg/l) | | | | | |
|---|---|---|---|---|---|---|
| | Northampton | | Bradford | | Brighouse | |
| | DWF | Overflow | DWF* | Overflow | DWF | Overflow |
| Suspended Solids | 320 | 391 | 232 | 237 | 113 | 637 |
| Permanganate Value | 78 | 41 | 86 | 29 | 52 | 53 |
| BOD | 311 | 81 | 257 | 43 | 199 | 86 |
| Ammoniacal Nitorgen | 43 | 3.8 | 31 | 3.1 | 25 | 4.9 |

* The figures are those quoted for a hypothetical overflow with a setting of 8.7 DWF.

The concentration of BOD and suspended solids was checked against time from previous storm and, although reporting considerable scatter, the following table gives the approximate values measured.

| Time Interval Between Successive Storms | Suspended Solids (mg/l) | | | BOD (mg/l) | | |
|---|---|---|---|---|---|---|
| | Nor. | Brig. | Brad. | Nor. | Brig. | Brad. |
| 1 hour | 400 | 400 | 300 | 160 | 70 | 40 |
| 12 hours | 700 | 700 | 260 | 280 | 120 | 50 |
| 5 days | 1800 | 1000 | 330 | 600 | 180 | 60 |

The origin of the suspended solids at Northampton was concluded to be depositions in the old sewer system. At Brighouse, it was believed to be carried in with the surface water during the storm. At Bradford the results were difficult to reconcile. Although the average suspended solids during the first five minutes of overflow discharge was double that of the crude sewage, there was no relation between peak levels and time intervals.

A very comprehensive analysis of these results is given and the studies amply demonstrated the difficulties of this type of research.

The final conclusion was that the Bradford results were inconclusive, but at Northampton the provision of storage of either two or six hours DWF would be equivalent to raising the setting of the hypothetical overflow from 6.2 DWF to 9 and 12 DWF, respectively. At Brighouse providing tanks of one, two or six hours capacity at the existing 6.2 DWF overflow would be equivalent to raising the setting to 9, 11 or 28 DWF.

The work described by Hedley and King [42] also showed the increase in suspended solids and BOD relative to the interval between storms, but in over 250 samples no relationship could be found between suspended solids and BOD in the storm flows. The authors also concluded that, since the major part of the polluting load is carried in solution or fine suspension, there could be no possibility of designing a storm water overflow to achieve quality separation.

The Storm Sewage Overflow Symposium [41] contains data similar to those referred to above. One discussion quotes the Trent Authority requirement that storm tank discharges should not exceed 150 mg/l suspended solids; no BOD standard is imposed, and at storm overflows the authority required only that a certain flow shall be passed to the sewage plant, generally six DWF.

## 5.7 Research

Research is undertaken by a variety of organizations and institutions and it is probable that there will be a greater coordination of effort in the future for several reasons.

In the first place, the reorganization of the water industry has resulted in a single body having overall responsibility. Secondly, in early 1974, the Department of the Environment had established a Working Party to investigate current storm water design practice in the U.K. This party is now functioning, but has become the responsibility of the National Water Council.

The terms of reference are as follows:

" To examine all aspects of the hydraulic design of systems for the conveyance of storm water from developed areas; to assess and co-ordinate research projects in progress; to promote any necessary new research both in the laboratory and in the field; and to publish guidance and produce a manual of good practice for the design of such systems."

Membership on the Working Party is drawn from all sides of the industry, and servicing of the Working Party is being undertaken by the Hydraulics Research Station.

While the Working Party is required to complete its report by 1976, it has already determined that the quality aspect of storm sewerage overflow should be ignored at the present time and attention should be directed at only the quantitative aspects of storm flows and the production of economical network designs.

One of the first tasks undertaken by the Working Party was to identify all research projects currently in hand in the U.K. relating to storm drainage, the second to determine current design and performance. Answers to questionnaires distributed by the Working Party concerning research projects have been returned and are summarized in Table 9. Replies to those concerned with design and performance were not expected to be complete until mid-1975.

TABLE 9. CURRENT RESEARCH IN THE UNITED KINGDOM

| SUBJECT | DETAIL | LOCATION |
|---|---|---|
| Meteorology | Validity of Bilham Equation | Leeds University |
| | Urban Effects on Precipitation | Queen Mary College London |
| | Small Scale Structure of Rainstorms | University of Lancaster |
| | Rain Gauge Network Designs | Imperial College London |
| Catchment Studies | Storm Runoff | Univ. Newcastle-upon-Tyne |
| | Mathematic Modelling in Urban Hydrology | Univ. of Southampton |
| | Hydrological Impact of Urbanization | University College London |
| | Gloucester Joint Water Study | University of Bristol |
| | Progressive Affects of Urbanization | University of Exeter |
| Flow in Pipes | Bed Movement in Circular Channels | Univ. Newcastle-upon-Tyne |
| | Flood Pulses in Pipe Flow | University of Lancaster |
| | Polymer Additives to Sewer Flows | University of Bristol |
| | Floodwaves in Storm Sewers | Lanchester Polytechnic |
| | Supercritical Free Surface Flow at Bends in Steep Pipe Lines | University of Manchester Institute of Technology |
| Structures | Siphon type Overflows | Loughborough University |
| | Vortex Storm Overflows | Newcastel Polytechnic |
| | Steeped Spillways for Reaeration | University of Birmingham |
| | Storm Overflows with Drop in Invert | University of Manchester Institute of Technology |

| SUBJECT | DETAIL | LOCATION |
|---|---|---|
| Design Methods | Computer aid in Drainage Design | Aston University |
| | Hydrological Consequences of Urbanization | Imperial College |
| | Urban Drainage as a Hydrologic System | University of Birmingham |
| | Mathematical Modelling of Rainfall and Runoff | Sheffield University |
| | Statistical Treatment of Urban Runoff Data | Sheffield University |
| Economics | Estimating the True Cost of Drainage Works | Aston University |

In addition, the following seven separate research establishments are working over the same broad field as the universities and polytechnics.

Building Research Establishment, Garston
Gloucester Joint Water Study, Severn Trent W.A. Tewkesbury
Hydraulics Research Station, Wallingford, Oxfordshire
Institute of Hydrology, Crowmarsh Gifford, Wallingford
Local Government Operational Research Unit, Reading
Meteorological Office, Bracknell
Water Research Centre, Stevenage (also Water Research Centre, Medmenham)

Separate from the above, but represented on the Working Party and working closely with all interested organizations, is the Construction Industry Research and Information Association. Its Sectional Committee for Hydraulic and Public Health Engineering includes many names included in the Working Party. CIRIA is a voluntary grant-aided industrial research association with one of its objects being the identification of needs for research and development. To this end it has prepared a classified index of Research Requirements in Hydraulic and Public Health Engineering. This publication was issued in draft for comment in 1972 and includes a list of those CIRIA research projects which had been completed by November, 1973. CIRIA sponsored the Research Colloquium held at Bristol University in April, 1973.

# 6. GERMANY

## 6.1 Governmental Structure

Since 1946, the German administration has been organized into Municipalities, Counties and Landers in each of the three zones of occupation. There are eleven Landers, three of which are the cities of Bremen, Hamburg and Berlin. The Federal government, headed by a Federal President, is responsible to the Bundestag, which constitutes 518 members of parliament, including 22 representatives from Berlin.

A second chamber, known as the Bundesrat, was created as a "Federative organ" of the Federation. It comprises 41 members appointed by the Lander Governments, as well as representatives from West Berlin. These members are bound by the instructions and provisions of their governments. Numerous Federal laws can be passed only if the Bundesrat gives its expressed consent.

Inasmuch as the Municipalities enforce Federal Lander legislation, they are subject to supervision by the Lander, and they must follow the instructions of the Lander for state tasks undertaken by them. The Landers, therefore, have a predominent influence over both the Federal legislation and its enforcement by the Municipalities.

At the present time, the State cannot legislate in matters of environmental protection. Although legislation has been passed and draft laws prepared which the State would like the Landers to adopt, it has been unable to put these into practice because laws to amend the constitution require the affirmative vote of two-thirds of the members of the Bundesrat and Bundestag.

## 6.2 Historical Background

Sewage systems have been constructed in German cities for over 100 years. Hamburg recently celebrated the 125th anniversary of its wastewater system [44]. Rising water consumption, new urban development and the lack of construction during the war are causing new concepts to be developed. In 1968, its total sanitary sewage flow was estimated at more than 5 million cubic metres per year, of which only 59% received mechanical and biological treatment. The remainder was discharged untreated. By comparison, the storm sewage flow is estimated to be 2.8 million

cubic metres per year and it may be anticipated that the current public awareness of the pollution problem will cause an intensification of the extensive investments made in recent years to improve the environment.

## 6.3 Authorities

### 6.3.1 Main regulatory authorities

There are basically three separate levels of regulatory authorities. The Federal level, which exercises influence over policy, the Lander level, which is the strongest and most practical power, and the Conservation Authorities.

The names of the Federal authorities and their responsibilities are as follows:

| Authority | Responsibility |
|---|---|
| Interministerieller Ausschuss Wasser (Interparliamentary Water Committee) | Water and sewage questions exceeding Lander responsibility or interest. |
| Interparlamentarische Arbeitsgemein schaft (Interparliamentary Working Committee) | Consists of Federal and Lander members of parliament. Federal organization for dealing with a number of legislative areas including water supply, wastewater treatment, costal water protection and research. |
| Der Bundesminister fur Ernahrung, Landwirtschaft und Forsten (BML) (Fed. Dept. of Food, Agriculture and Forestry) | Together with the Lander they follow the financial aspects of the areas specified immediately above. |
| Der Bundesminister fur Gesundheitsesen (BM Ges) (Federal Dept. of Health) | Health aspects of water supply and wastewater, air and noise pollution. |

In each Lander there is a Wasserwirtschaftsverwaltungen (WWA) with a central office, in addition to local offices in the larger cities. They approve projects and are represented centrally in the country by the Landerarbeitsgemeinschaft Wasser (LAWA) which is a central authority for water and sewerage technology and law. Its purpose is to have common problems solved collectively and to issue recommendations. The central

organization, the LAWA, moves its headquarters every two years from one Lander to another, and thus, overall, is located for an equal time in each Lander.

The third, often very strong regulatory authority, consists of the eight main conservation authorities. These have been formed where the situation has become critical, and although their influence and work varies from one Lander to another, they may have complete charge of water supply and wastewater treatment within their area. Their responsibility can include the construction and operation of treatment plants.

The basis for the Lander legislation lies in the "Federal Water Act" with its basic principle being "that water may not be used without a permit issued by the authorities, subject to any provisions to the contrary contained in the Act or in the regulations issued by a Lander in accordance with the provisions of this Act". The Act imposes licensing requirements on conservation authorities, specifies that "certain waters should be protected against detrimental effects in the interests of the public water supply, that underground aquifiers should be recharged", and "that the harmful effects caused by the runoff of rainwater should be prevented". In addition "any person who introduces or discharges any matter into waters or takes any action which results in their physical, chemical or biological constitution being changed shall be liable to make good damage caused to any other person as a result of this action. If several persons were responsible for the action, they shall be jointly and severely liable for any damage" [45].

In addition, each Lander has its own laws (Landeswassergestz), established by 1962. In October, 1964, these laws were compared with the Federal Act, and it was concluded that the Federal law was not adequate. Since December, 1970, work has been proceeding in order that the Federal Law may be changed to accord with the "Program for the Protection of the Human Environment", which has the following as its five main goals [46]:

1) To promote long term environmental planning, through updated protective legislation and the integration of the regulatory authority.
2) To establish the principle "the polluter pays" (originator principle).
3) To establish a technology for environmental control compatible with economic criteria.

4) To increase the general public awareness of its environment.

5) To promote international cooperation.

The Federal government is presently attempting to coordinate the legislative efforts of the various Landers in order to establish a national policy.

### 6.3.2 Subsidiary authorities

In addition to the large self-governing authorities, there are others which have limited responsibilities such as water supply (municipal and industrial), wastewater treatment, receiving water regulation and quality, and the assurance of recreation areas and/or an ecological balance. These often may serve public interest by providing support for, or against, a particular project at public hearings, although the elected representatives of local government normally fill this function. The hearings themselves may derive from private citizen initiatives. These groups often have considerable influence on decisions, partly because of participation by the academic communities.

The Abwassertechnisehen Vereinigung (ATV or Wastewater Technical Association) is a professional society concerned with wastewater treatment associated pipelines and other relevant works.

A new association was formed in 1971 called the Dokumentatronszentrale Wasser (Central Library for water and wastewater publications). In addition to the obvious field of interest, it also includes hydromechanics, water chemistry, geology, meteorology, biology, etc. [47].

The Deutscher Normenausshuss (German Standards Association) compile and publish (DIN) standards.

International authorities have been established with responsibilities for the Bodensee and the Rhein. Their responsibilities include the provision of technical guidance through their publications (e.g. [48]) dealing with storm relief devices.

## 6.4 Financial Considerations

Conservation authorities are financed by member municipalities and industrial contributions and/or fees. Additional money is made available through Lander and Federal funds.

If a project is approved by the authorities and if it is constructed to at least minimum standards set by the government, then subsidies are available. These amount to approximately 32 percent for new sewers and 26 percent for treatment plants, with local variations as high as 50 percent.

The funding authority ensures that the subsidies are properly utilized to further its policies and that the standards of design and construction are in accord with its requirements.

## 6.5 Design Practices

### 6.5.1 Sanitary sewers

New sanitary sewers are usually designed as gravity sewers. In some of the low-lying cities with limited natural fall, many sewers are designed to flow full all the time. The flow is initiated by surcharging. In addition, pressurized sewers exist in connection with lift stations. Pressurized and vacuum sewers have been constructed only where special conditions have rendered gravity systems uneconomical.

Experience exists with pressure sewers [49] from two areas with slopes as nominal as one in 5,000 and a very high water table. One area has a population of 1,400 and the other 80 year-round plus 1,000 seasonal. Including pumps and tanks, the construction cost was stated to be only 20% of a gravity system. Each household is responsible for the cost of the individual tank and operation. It is claimed that this does not cost more than the average gravity system connection. Although it is admitted that further developmental work is necessary, it is considered that the system is ready for practical use when economically justified.

Another municipality has used pressure sewers having a total length of 260 miles for almost 100 years. Pressures up to approximately 180 psi are used. The pipes are usually made of ductile iron, but cement-lined steel pipes and asbestos cement pipes are also used. Another city has allowed pressurized sewers since 1974, subject to city criteria.

In the case of partially separated sewer systems, the practice as to what source of wastewater drains into the sanitary and storm sewers, respectively, varies from one municipality to the next. The basic principle

is that no sanitary sewerage should drain into the storm sewer system.

The maximum capacity of sewage treatment plants is usually twice the dry weather flow for biological treatment, although wide variations exist [47]. One city considers it favourable to treat 2.6 times the dry weather flow. Many provide 5.1 times the dry weather flow with biological treatment and 8.6 times the dry weather flow with mechanical treatment. In one Lander, numerous plants are capable of providing 17 times the dry weather flow with mechanical treatment. In addition to this rather high treatment capacity, storm holding tanks with a capacity of 15 - 25 minutes detention with sedimentation are provided.

Direct comparisons with German dilution figures cannot be made, since the dry weather flow is established by distributing the total daily flow over 14 hours, instead of 24 as is done in North American practice. The figures quoted in the above paragraph have been converted to the North American practice. It should be noted that design flow is shown as an addition to the dry weather flow. For example 1 + 3 is four times dry weather flow [47].

### 6.5.2 Storm sewers and treatment

A one-year storm of 15 minute duration is the storm most used for new sewer systems, although two-year storms are used in some municipalities for densely populated areas or special structures, such as tunnels or storm holding tanks.

There is substantial conflict as to how runoff should be calculated. The various methods are given in references 47 and 50-56. The most common method of computing runoff has been Reinhold's method. But a consensus of opinion is that this method should not be used for larger municipalities. One Lander considered the limiting size to be 5,000 inhabitants. Runoff values for different geographical areas for the one year storm are given in the design handbooks, together with modifying formulae for calculating other storm intensities.

The storm hydrograph, which is used in the Keser method, is based on the design storm derived from long term measurements taken prior to and after the second world war. It is considered inadequate by some observers, since up to 50% of the storms do not conform to the curve and its frequency is not known [50].

The rational method for computing runoff is gaining ground, especially as cities grow, but some of the larger cities are using simulation models and computers, and for these several synthetic storms are usually considered to prove the model.

To date, new storm sewer systems have not been concerned with the quality factors due, no doubt, to the priority of catching up with untreated sanitary sewage. It is interesting to note, however, that new sewers are usually designed as combined systems on the assumption that both the sanitary and storm sewage will have to be treated in due course. The storm sewer is only separated when the pollutional storm water load is low and the receiving waters are suitable.

A notable exception is the city of Hamburg, which is low-lying, and where all new construction will be of separate systems. Here, however, it has been decided that the first flush shall be treated, but the design method has not been determined. This anticipates the proposed new legislation which will require that storm water and overflows shall be treated.

The majority of designers and authorities design sewers for gravity flow, but allow infrequent surcharges provided no damage is caused to serviced lots. In one case, most sewers flow completely full since the city is flat and the system is submerged [44, 47].

### 6.5.3 Storm runoff attenuation and detention systems

Storm runoff is frequently attenuated by storage in holding tanks or artificial ponds and occasionally ponded in order that groundwater might be replenished. Although not mandatory, it is quite common to use interlocking concrete blocks instead of an impervious cover for sidewalks and boulevards, thus increasing infiltration.

Storm holding tanks are commonly constructed at sewage treatment plants except where the systems are separate, and even if the tank is not constructed immediately, space is reserved for later construction. The tanks are usually designed to ATV standards which require a 15 to 20 minute detention period based on the difference between maximum combined sewer flow to the plant and the plant mechanical treatment capability. The construction cost is considered to be the prime factor determining detention period in storm holding tanks [57, 58].

Local conditions, as well as hydraulic maintenance and cost criteria, determine the type of storm storage system to be used, but there is a definite preference for constructing the tanks as fully covered below ground structures. Very often they are located in natural depressions and, occasionally, large diameter parallel pipes have been used to increase the storage. One of their main problems is the sedimentation which occurs within the tanks and ATV publications [47, 59] give recommendations on how this and the associated digestion may be avoided. Also, in order to decrease maintenance costs, automatic scrapers and high pressure jets are installed for cleaning out the base.

Provision is often made for treating the capacity of the tank within the tank, although the sediments are always pumped to the main plant for treatment. Although the treatment plant effluent is limited by law to a maximum BOD value of 25, this is not enforced by many of the Landers and the newly drafted law proposes a gradual decrease in the COD requirements for storm water from 80 through 40 and 15 to 0; this is not considered practical by many observers.

Field studies of sewer systems have been carried out both to check flow and quality. Field studies are not commonly undertaken since personnel and funds are stated not to be available to conduct them properly. Consequently, some researchers have criticized the measurements already taken by those municipalities on the basis that the results do not justify the expenditures made.

### 6.5.4 Overflows

There is no fixed policy regarding the control of overflows, although where a policy is established it is usually based on the quality of the receiving stream. An ATV publication [60] requires a dilution of the dry weather flow between 1 x 8.6 to 1 x 12 before overflow takes place; it is anticipated that this may be increased in the near future to 1 x 19 or 1 x 36.

The efficiency of present design standards has been investigated [59, 61, 62] and new proposals made. One author considered that the number of rainfalls with determined intensities, and the intensities of rainfalls preceeding or following heavy storms, are of great import-

tance for the design of storm sewers and their special structures. These influences have been analyzed by means of evaluation of rainfall measurements. The intervals between successive storms are presented, which must be taken into account when computing retention basins.

Runoff coefficients, which are variable with time, have a great influence on overflow data, especially for steep slopes of urban surfaces, and on the volume of retention basins. New proposals for the calculation of these basins have been submitted.

The most common form of overflow is the weir. No attempt has been made to have the overflows controlled on a quality basis, nor has any work been done on dynamic regulators. American research is followed closely and in Hamburg it is planned to use inverted siphons to prevent the deposition of solids. Computers have not been used to maximize storage within a sewer, but is planned in one location, although it is felt that this is slightly premature and that the necessary probes and sensors have not the high degree of reliability required for such a system. The general feeling is that a more effective and reliable system could be achieved through increased overflow dilution rates and the construction of combined sewer clarification tanks and detention systems [58, 62-66].

### 6.6 Quality

The Ministry of the Interior recently requested that the consultant firm of Rudolf Lautrich VBI and Dr. Ing. R. Pecher prepare an "opinion report" (Gutachten) on the subject of runoff from urban areas and its effect on recipient pollution. It was published early in 1974, and contains an up-to-date account of the quality and composition of sewage and a comparison between combined and separate systems. The effect of the runoff on the recipient quality was analyzed for both separate and combined systems. The determined difference between the composition of storm and sanitary sewage is given in Table 10 [67].

Using average population densities and sanitary sewerage loads, the average yearly pollution load discharged to receiving waters was computed. These values, summarized in Table 10, have been included in the

TABLE 10. AVERAGE COMPOSITION OF STORM AND SANITARY SEWAGE, GERMANY

| Parameter | Unit | Storm * Runoff | Sanitary ** Runoff |
|---|---|---|---|
| $BOD_5$ | mg/l | 40 | 400 |
| COD | mg/l | 125 | 800 |
| Total solids | mg/l | 1,390 | 1,200 |
| Suspended solids | mg/l | 773 | 600 |
| Volatile solids | mg/l | 2.1 | 80 |
| Total phosphorous | mg/l | 1.9 | 20 |
| Total coliform | no/ml | 2,500 | $10^6$ |

* Yearly mean

** Based on 150 litres/person/day

effect of storm runoff from urban areas. They have been estimated with the assistance of numerous investigations, and data obtained from various domestic and foreign reports and research. Comparisons were also made with foreign data.

The quantity of storm runoff was computed to be 250,000 Igal/acre/year (2,800 $m^3$/ha/yr), compared with 446,000 Igal/acre/yr sanitary sewerage (56%). A comparison with the United States indicated that the ratio there is in the order of 40%.

Next, the content of pollutants was established for both separate and combined systems, and their effect on the recipient was computed Allowance was made for the mechanical treatment of storm water in separate systems, and biological treatment for the storm water that does not overflow in combined sewers.

It was found that the annual load of pollutants in a separate storm water system was similar to the loading from a biological treatment plant. By treating all storm water in a separate system with the help of sedimentation tanks, the pollutional load could be decreased to half of that of untreated storm water.

The value at which overflow begins is called the "critical rain intensity". Commonly used today is 0.071 cu ft/sec/acre. This value results in a recipient pollutional load similar to that of a

separate system biological treatment plant effluent, because of the storm runoff in the combined system. If the critical intensity is raised from 0.071 to 0.213 cu ft/sec/acre the recipient pollutional load can be reduced to half. Further reduction can be obtained by constructing detention systems such as storm holding and overflow tanks. If the critical rain intensity exceeds 0.213 cu ft/sec/acre, little is gained by constructing detention systems, except for the reduction of shock loads on the system.

One study [68] indicated that the quality of storm sewer runoff can be improved by:

1) increased street cleaning;
2) cleaning catch basins regularly;
3) continued air pollution abatement and control; and,
4) construction of storm holding tanks with 10-20 minutes detention time and treating sediments.

However, the cost of construction, operation and maintenance of the holding tanks is high in comparison with their effectiveness.

A study on combined sewer runoff quality [69] questioned whether biological treatment to above 90 percent $BOD_5$ reduction (no values above 20-25 mg $BOD_5$ litre) is necessary and suggested that government guidelines be reassessed. The same author considered that a combined system arrangement with overflows and storm holding tanks could economically treat up to twice the dry weather flow, providing the following criteria were met:

1) The holding tank, once filled, should retain its load until the storm is over.
2) Content of tank should go to biological treatment.
3) The tank volume must be sufficiently large to allow storage for a design storm of 15 minutes duration.

In addition, the load that could be applied to a recipient would be dependent on its subsequent uses and on its self-cleaning ability.

If the recipient is sensitive, it must be kept free of additional load. An increase in treatment plant capacity is concluded to be technically difficult and economically unjustified. The treatment of storm

runoff, which is technically simple, is considered a more economic measure.

### 6.7 Cleaning Practices

Downtown and suburban streets are usually swept weekly. Local variation occurs, with downtown streets generally being swept more frequently. For this purpose mechanical sweepers are used. It is considered that streets are cleaned for sanitary and aesthetic reasons.

Snow is usually ploughed to the side of the road and left to melt, except on downtown streets where it may impede traffic. Here it is removed and dumped, either in rivers or at snow dumps. However, most cities do not consider snow a major problem since storms are infrequent except in southern Germany. Likewise, the use of salt as a de-icing agent is very limited, and heavy metals are not considered serious snow contaminants.

The most common method of maintaining sewers is by high pressure flushing. Some cities use a cleaning shield, which is a device that is inserted in the sewer causing the water to back up on the upstream side with a small discharge at the base causing sediments to be flushed downstream as the shield moves slowly through the sewer; sewers are not flushed during dry weather. Catchbasins are installed on new storm sewers and these are usually cleaned twice a year by suction pumps.

### 6.8 Standards

Uniform standards are followed only to a limited extent, with the exception of those from two organizations, whose publications are usually adhered to firmly by The Water and Sewer Technology Approval Authorities of the various Landers.

The first are the DIN standards which deal with material specifications, excavation criteria and limited design guidelines. Secondly, the ATV publishes guidelines and directives for the construction of treatment plants, sewers and related structures. Among the more interesting are directives for choosing between a combined or separate sewer system, and directives for designing overflows in combined systems. In 1973 the ATV also published a sewerage system design handbook which

includes recent methods of computing runoff, storage volumes, etc. In all, these provide a good account of the present technical state-of-the-art in Germany [47, 57, 60, 70, 71, 72].

It is the opinion of some observers that the ATV design guidelines are becoming outdated by recently acquired knowledge and changing requirements.

## 6.9 Benefits Achieved

It is the opinion of some that, by the construction of treatment plants and holding tanks, the Germans have only just managed to prevent an increase in the total pollution load to its lakes and streams. The reasons are several, but the most outstanding is the war and its after effects. Post war construction only gradually resumed in the 1960s. Additionally, the growth of industry has been phenomenal, thus resulting in substantially greater loads to be handled by treatment plants and receiving waters.

Exceptions definitely exist, such as the Ruhr and Seen, where definite improvement has been achieved through extraordinary abatement schemes.

## 6.10 Research

Most research in Germany is funded through the Federal Ministry of the Interior (EM fur Forshung & Technologi, 53 Bonn Postfach 9124, Heusallee 2-10) and through a German research organization (Deutsche Forschungsgemeinschaft). The research is generally carried out by the universities and the large Conservation Authorities central laboratories.

The fields into which the majority of research is, and has been, directed deal with the amount and quality of urban runoff, mathematical models for hydraulic computation, and quality assessment of sewer systems and recipients.

It was not possible to identify all the research projects being undertaken, but it was noted that Aachen University is undertaking a study into the composition of storm runoff, and Dortmunder University is studying the oxygen demand on the recipient streams using a simulation model. Analyses of a sewer network simulation model are being initiated

at both universities for conventional flow and non-steady flow, including pollution load parameters. At the University of Hanover two interesting projects are being studied. The first concerns a multi-variable statistical analysis of the characteristics which cause precipitation variations, such as nonuniform rainfall, distribution, storm centre and storm tracks, quantity and duration. The second model is using results from the first to calibrate a simulation model for urban watersheds based on the unit hydrographs theory and applying it to areas with very different characteristics of size, slope, runoff coefficients and conduit geometry.

A number of researchers considered that more work should be done on the determination of the sewer system mathematical models input hydrographs, the physical measurement of flow in sewers, and also in proving the capabilities of the numerous available models. Another source considered the Dorsch and Kock-WRE models to be the only well-developed and proven models in Germany today.

Money is considered available for research in Germany, but unfortunately there is a lack of centralized coordination and guidance. Since much research is done at the universities and is tied in with the prime objectives of obtaining academic degrees, the work is not always tailored to the best needs of the practicing professions in the pollution abatement field.

Table 11 is a list of some of the ongoing and completed projects. Unfortunately, the short time allowed for this study made it impossible to obtain a complete list of relevant research.

TABLE 11. CURRENT RESEARCH IN GERMANY

| Project Description | Institution & University |
|---|---|
| Composition of Storm Runoff (Results to be available 75/76) | Lehrstuhl fur Siedlungswasserwirtschaft<br>Rheinisch-Westfalische Technische Hochschule Aachen<br>51 Aachen<br>Mies-vah-der-Rohe Strasse<br>Templergraben 55 |
| Recipient Load Model Based on Oxygen Demand | Das Ubergreifende Institut fur Umweltschutz und Umweltguteplanung<br>Universitat Dortmund<br>46 Dortmund<br>Haus Weichen<br>Rosemeyer Strasse 6 |
| Sewer Network Simulation Model<br>a) Conventional analysis<br>b) Unsteady flow, including surface runoff and pollutant load parameters | Das Ubergreifende Institut fur Umweltschutz und Umweltguteplanung<br>Universitat Dortmund<br>46 Dortmund<br>Haus Weichen<br>Rosemeyer Strasse 6 |
| Precipitation Analysis-Precipitation Statistics (Applying the multi-variable variance analysis as a statistical method, being done in hydrology for the first time, it is possible to determine area-depending precipitation characteristics such as nonuniform rainfall distribution, storm centres and storm tracks, rainfall quantity and duration, on the basis of probability theory) | Lehrstuhl und Institut fur Wasserwirtschaft, Hydrologie, und landwirtschaftlichen Wasserbau<br>Technische Universitat Hannover<br>D-3000 Hanover<br>Callinstrasse 15 c |
| Rainfall Runoff Prediction in Combined Sewer Networks. (Calibration of a simulation model for urban watersheds which is based on the unit hydrograph theory applicable to areas with very different characteristics such as size, slope, runoff coefficient and conduit geometry. Simulation of recorded rains for the determination of the actual runoff frequency, sewer overflow volumes and the organic pollution to the recipients.) | Lehrstuhl und Institut fur Wasserwirtschaft, Hydrologie, und landwirtschaftlichen Wasserbau<br>Technische Universitat Hannover<br>D-3000 Hannover<br>Callinstrasse 15 c |

Quality analysis of overflows with continuous sampling in order to relate the pollution of the recipient before and during the storm.

Evaluation of long term organic pollution for recipients and establishing criteria for the design of overflow structures.

Solving the St. Venant equations by applying a hybrid computer. (This has been done for a sewer-storm detention tank - throttled discharge pipe system and good agreement has been reached with actual events. Hybrid simulations of meshed sewer networks are developed which permit future regulation of sewer systems.)

## 7. SWITZERLAND

### 7.1 Governmental Structure

In Switzerland, there are three levels of government: the Confederation, corresponding in some ways to the Canadian Federal Government; the Cantons, similar to the Provinces; and, the Communes, equivalent to Municipalities. However, the authority of each level of government varies greatly from that exercised by the Canadian counterparts, in that the Communes have a very high degree of autonomy, while the Confederation has authority only in certain areas. Outside these areas, conformity to requirements is by persuasion - usually in the form of grants - rather than by legislation.

In the field of environmental protection, the Confederation has passed certain regulations; enforcement is by witholding grants.

### 7.2 Background

This country was formed by a comparatively loose association of the various Cantons and Communes for defense against invaders, and the development of the country has followed this pattern. The Cantons have considerable authority, while the Communes are very autonomous and jealously guard their right to govern thier own affairs, while the Confederation has little authority over local matters. However, it is generally accepted that, in matters of general concern, the Confederation will, as a representative body of the whole country, produce regulations which everyone will follow.

Switzerland is a basically rural country, with few large cities and little heavy industry. It has practised environmental control for many years, to such an extent that the penalty for cutting down trees without permission was, at one time, death.

### 7.3 Authorities

#### 7.3.1 Main regulatory authority

The main regulatory authority is a national body, the Federal Office for the Protection of the Environment in Berne.

### 7.3.2 Subsidiary authorities

In regard to sewerage and drainage, it is not totally correct to call the Cantonal authorities subsidiaries, as they exercise as much, if not more, authority over the Communes than the Confederation. In any case, the Cantons have the power to apply stricter controls than the Confederation requires.

### 7.4 Financial Considerations

Financial considerations naturally play a role in the establishment of sewerage systems and construction of treatment facilities. Basically, each Commune is responsible for funding the cost of installation and operation of new facilities. However, to encourage the Communes to install sewerage systems and treatment plants, both the Confederation and the Canton in question make grants to the Communes for the construction costs.

The federal grant system is applied right across the country, while each Canton has its own method of assessing the contribution that the Cantonal authorities will make to the communities under their jurisdiction.

Under the grant structure for the Canton of Vaud, the cost of a sewerage system is divided by the number of persons served by the system, and the rate of subsidy is then read from a table, in terms of the financial capability of the community. This rate can vary from 20% for Class 1 (very rich) to 50% for Class 12 (very poor).

Under the Federal plan, the rate of subsidy is tied to the National Defence budget (the federal income tax paid). The taxes paid are then compared to the average across the country, and the rate of subsidy is adjusted as shown in Table 12.

It should be noted that the financial status of the Canton in which the community is established is also taken into account in calculating the subsidy.

The combined federal and cantonal grants in the Canton of Vaud, for example, can reach a maximum of 90% of the cost of the works.

TABLE 12. SWISS FEDERAL SUBSIDIES FOR SEWERAGE SYSTEMS

| Federal tax paid in the community as a percentage of the average for the whole country | Federal Subsidies (%) Cantons with a low financial capability | Cantons with a medium financial capability | Cantons with a strong financial capability |
|---|---|---|---|
| to 20% | 50.0 | 40 | 30.0 |
| 20 to 40 | 47.5 | 38 | 28.5 |
| 40 to 60 | 45.0 | 36 | 27.0 |
| 60 to 75 | 42.5 | 34 | 25.5 |
| 75 to 90 | 40.0 | 32 | 24.0 |
| 90 to 100 | 37.5 | 30 | 22.5 |
| 100 to 110 | 35.0 | 28 | 21.0 |
| 110 to 120 | 32.5 | 26 | 19.5 |
| 120 to 125 | 30.0 | 24 | 18.0 |
| 125 to 130 | 27.5 | 22 | 16.5 |
| 130 to 135 | 25.0 | 20 | 15.0 |
| 135 to 140 | 22.5 | 18 | 15.0 |
| 140 to 145 | 20.0 | 16 | 15.0 |
| 145 to 150 | 17.5 | 15 | 15.0 |
| Over 150 | 15.0 | 15 | 15.0 |

If, during routine pollution control tests carried out by the authorities - usually the Canton - or following complaints by neighbouring communities or individuals, a definite need for treatment facilities is shown to exist, it can be seen that financial considerations play only a minor role in the decision to install them.

## 7.5 Standards

The selection of a combined or separate system for a particular municipality is normally made on the basis of a benefit/cost appraisal of the various possibilities; no definite doctrine is established by code. However, in general, new networks connecting into existing systems are similar to those into which they discharge, while completely new networks tend to be separate.

The main standards for calculating storm runoff are issued by the Swiss Standards Association (SNV), and consist of three separate directives. SNV 640 350 governs the determination of the rainfall intensity, 640 351 the time of runoff, and 640 352, the quantity entering the drainage system. These may be briefly summarized as follows:

Rainfall intensity is based on the formula

$$r = K/(T + B)$$

where $r$ = the mean intensity during a period of T minutes for a "z" year storm (litre/hectare)

$K$ = a coefficient of the interval "z" and the location

$z$ = the interval during which the rainfall has reached or exceeded a given quantity (years)

$B$ = a constant for a specific location (minutes)

$T$ = duration of the rainfall (minutes)

The constant K is given in the standards for each zone for 1, 2, 5, 10, 15 and 20-year storms, and B is given for each zone. Both constants have been developed as a result of pluviographic measurements at different stations, and by the application of statistical analyses.

Runoff time ($T_A$) is dependent upon the length of the line of drainage (LA in metres), drainage coefficient $\Psi$ which depends upon the ground cover, the coefficient K (from rainfall intensity) and the mean slope of the line of drainage (%).

$$T_A = (12\ L_A)/\ (\Psi^{5/3}\ K^{2/3}\ \sqrt{J}) + 5$$

The total quantity is calculated by the formula

$$Qr = (F^{RED} + a\ F_2^{RED})\ r$$

where $F^{RED}$ = the surface of the roadway and the adjacent ground, reduced by the appropriate flow coefficients

$F_2^{RED}$ = the remainder of the contributory area, reduced by its flow coefficient

$r$ = intensity of rainfall

$a$ = a reduction coefficient defined in the standard

## 7.6 Design Practices

### 7.6.1 Sanitary sewers

Sanitary sewers are designed on a free-flow gravity basis, and great attention is paid to the actual construction in order to eliminate infiltration. All pipelines are tested under pressure; the maximum

infiltration permitted is 0.3 litres/sq metre of pipe wall/hour under a pressure of 0.3 metres of water.

The capacity of sewage treatment plants varies according to the local circumstance. Some are designed for only twice dry weather flow, while others have a capacity of five times dry weather flow calculated at the 14-hour concentration. To allow for future development, plants are designed for flows of 1.33 gal/sec/acre (15 litres/second/hectare).

Treatment is by mechanical and biological means, with some new plants being designed for chemical treatment as well. Storm water retention tanks are normally installed, and are sized to retain an amount equal to the difference between the admissible biological load on the receiving waters and the quantity overflowing. The contents of the tank are pumped back to the treatment plant for treatment.

### 7.6.2 Storm sewers and treatment

Storm sewers are normally designed for a 10-year storm of 15 minute duration. However, in some cities, a 20-year storm is used for midtown areas, a 10-year for surrounding residential, and a 5-year for more suburban areas.

Road drainage (freeways) is based on a 10-year storm within built up areas and a 5-year storm elsewhere.

Sewers are generally designed as free-flow gravity systems; surcharged systems are generally avoided because of the possibility of basement flooding. The quantity of storm water collected by the sewer system is arrived at by a comparatively simple but lengthy calculation elaborated in SNV Standard 640 352, which takes into account the types of ground cover, mean gradient of the catchment, time of runoff, etc.

Treatment of storm water discharges is not generally anticipated.

### 7.6.3 Storm runoff attenuation and detention systems

In general, storm runoff attenuation is practised by the installation of retention basins or tanks where a direct discharge would cause sudden rises in the levels of the receiving waters, or, in the case of combined system overflows, where the overflow would cause excessive pollution of the receiving waters.

In the case of retention tanks or basins on separate systems, no treatment is envisaged, while for overflows from combined systems, either the contents are discharged to the receiving waters without treatment, at a controlled rate, or they are pumped back and receive full treatment in the plant.

Local conditions are the prime consideration for attenuation and detention systems, but cost is also a determining factor. In most treatment plants or combined systems, if retention tanks are not constructed immediately, space is normally reserved for future construction.

Field studies are carried out to check the operation and state of existing systems, to measure flows and for maintenance purposes. Extensive studies are, however, rarely undertaken because of the amount of work required to produce what may be results of dubious value.

## 7.7 Quality

Up to the present time, very little attention has been paid to the quality of runoff or storm overflows. However, it is now becoming more recognized that quality is important when considering the overall effect of discharges on the receiving waters. The Swiss Federal Institute for Water Resources and Water Pollution Control recommends that, in combined systems, mechanical treatment be applied to light rainfalls, heavier falls be diverted to holding tanks fitted with scum-boards, the contents of which are cycled through the treatment plant, and heavy storms be diverted directly to the receiving waters. Thus, the first flush will be caught and held for treatment while the following waters will be diverted without treatment.

## 7.8 Cleaning Practices

Cleaning of the streets is a municipal matter and varies considerably with the community. In Zurich, downtown streets are swept ten times a week, and washed as required at very irregular intervals. Suburban roads are swept at much less frequent intervals and washed depending on the necessity and the weather. In Lausanne, downtown streets are swept once a day and washed once a week, while suburban streets are swept once a week and washed once a month.

Sewer cleaning is again up to the municipalities and various systems have been set up. In the old City of Zurich, sewers are cleaned every two months, while in other sections of the city they are cleaned every three years. In Lausanne, due to the gradients, cleaning is seldom required. In general, a systematic program has been established whereby all the sewers in a network are cleaned every three years.

Catch basins are cleared out by means of suction pumps or hand shovels up to three times a year.

Snow is normally just ploughed to the side of the road and allowed to melt. If there is a very heavy fall and the snow banks present a threat to the safety of people or vehicles, the snow will be removed and dumped into the lakes or rivers.

## 7.9 Overflow Design

No firm policy has been established regarding overflow design. Control is normally by side or end weirs; two types of regulators are often used, the "Leaping Weir" and single or double blade weirs. Normally the weirs are set to divert flows of more than five times the DWF.

## 7.10 Benefits Achieved

Due to the nature of the country and its receiving waters, storm water runoff and combined sewer overflows have had little overall detrimental effect, and it must be recorded that virtually no benefits have been achieved from storm water treatment, as little treatment has taken place. The main benefit that will be realized by the construction of future treatment plants will be the preservation of the quality of the water, rather than the rectification of a problem.

## 7.11 Special Considerations

Each city and region has to be recognized as having particular problems to be solved and visits were made to the City of Lausanne, the Canton of Geneva and the Bureau des Autoroutes du Canton de Vaud.

The City of Lausanne is built on seven hills and is characterized by the quite steep slopes, with only a small flat area along the lakeshore. For reasons of economy, the shoreline area is serviced with separate sewers, while the rest of the city has a combined system. Only

the shoreline area requires pumping stations, the rest of the city is drained by gravity to the treatment plant. The overflow weir diverts the storm flow when it exceeds 4.6 times the DWF, and the overflow is discharged directly into the lake without treatment.

Lausanne, until recently, swept all its streets by hand, but with the cost of labour rising rapidly, mechanical sweepers are now being used to a great extent. One peculiar problem that existed in the city, mainly due to the gradients on the streets, was dust generated by the use of studded tires on dry pavements. This dust was so fine that it was not picked up by the sweepers and so was flushed down the sewers by rain, did not settle out in the treatment plant, and appeared as an obnoxious, albeit inert, film on the surface of the lake. The problem had a very simple solution; studded tires have now been banned.

Cleaning of the sewers presents no problems. The slopes of the streets are sufficiently steep that velocities maintained are sufficient for self-cleaning. In fact, high velocities are more of a problem than low ones.

In the Canton of Geneva the problem of pollution by storm water is probably worse in the rural areas than in the cities. Farmers who find that a certain quantity of fertilizer per hectare will double the crop, will use three times the amount the next season. The plants can assimilate only some of the fertilizer and the remainder eventually gets washed into the watercourses because of the general ground gradients of the farm land, creating a high nutrient situation which contributes to a rapid plant growth. This will probably be overcome by education of the farmers, coupled with the rise in prices of petroleum derivatives.

In the cities, at the present time, the combined sewer system is virtually universal, but whenever new construction is realized, entirely separate systems must be installed as far as the property line. Thus, when a whole area is redeveloped, a truly separate municipal system can be installed at a minimal cost to the community.

There is no treatment of overflows from the existing combined system, and treatment of storm water is not anticipated when separate systems are installed in the future.

For the Autoroutes, design criteria are laid down by the Confederation, and all drainage systems are designed in accordance with the Swiss Standards Association documents SNV 640 350, 51 and 52 which detail the calculation methods for rainfall intensity, runoff time, and discharges, respectively.

When Autoroutes are constructed in accordance with the Confederations's requirements, the Confederation makes a grant to the Canton of a very substantial portion of the cost of such a highway.

Autoroute drainage is designed throughout for a 10-year storm. The quantity of water to be carried by any particular section of piping is determined by a lengthy, but comparatively simple calculation, the format of which is detailed in Standard No. SNV 640 352, taking into account the type of terrain adjacent to the section of highway, the time the water takes to reach the gutters, and the time it takes to run from one section of gutter to the catch basin, as well as the intensity of the storm and the catchment area.

Abrasives and chemicals are used in minimum quantities, and are not considered serious pollution problems. The chemicals are dissolved in the snow melt, and are sufficiently diluted to pose only a minor problem, while the abrasives are caught by the catch basins, which are cleaned out on a regular basis at least once a month.

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| | |
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| United Kingdom | Sir Alexander Gibb & Partners, Reading |
| United States | Water Resources Engineers Inc., Springfield, VA. |

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# APPENDIX I

## ADMINISTRATION OF RIVER POLLUTION CONTROL

## IN THE UNITED KINGDOM

## APPENDIX I

## ADMINISTRATION OF RIVER POLLUTION CONTROL IN THE UNITED KINGDOM*

1. The Secretaries of State for the Environment and for Wales exercise the central government functions relating to control of water pollution. These include power to direct the variation or revocation of a river authority's consent to a discharge; to confirm byelaws; to determine appeals; and to act in the event of default by a river authority. Guidance is given by circulars and technical memoranda to river authorities and sewerage authorities on various matters affecting water quality. There is close liaison between the Departments and river authorities and local authorities on both technical and administrative matters. Standing technical committees advise the Secretary of State for the Environment on the effects on rivers of the use of synthetic detergents and related products; and promote and co-ordinate studies of practical problems related to water quality both generally and in particular catchment areas. Other committees and working parties are appointed to examine special problems as they arise.

2. The executive powers for prevention of pollution of rivers and canals in England and Wales are exercised by twenty-nine river authorities**, including the Thames Conservancy and the Lee Conservancy Catchment Boards. In addition the Port of London Authority exercises powers over the tidal Thames and the Tidal parts of its tributaries, while the Greater London Council has responsibility for prevention of pollution in the non-tidal parts of the tributaries in the London Excluded Area. A bare majority of the members of the river authorities are appointed by the county and county borough councils or London borough councils in their area. The rest of the members are appointed by Ministers. The Secretary of State for the Environment, the Secretary of State for Wales and the Minister of Agriculture, Fisheries and Food, either individually or jointly, appoint one or more members qualified respectively in public water supply, industry other than agriculture, and navigation. The Minister of Agriculture, Fisheries and Food appoints one or more members

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* Report of a River Pollution Survey of England and Wales, 1970. Volume 1, Appendix 2.

** Prior to April, 1974.

qualified respectively in land drainage, fisheries and agriculture. Expenditure by river authorities on prevention of pollution is financed by precepts on the local authorities in their areas.

3. The Rivers (Prevention of Pollution) Acts 1951 and 1961 give river authorities powers to control discharges and outlets and to prosecute for the offence of causing pollution to non-tidal rivers. The only exemption from control is for new or altered outlets (but not the discharges) from sewage disposal works approved by the Secretary of State for the Environment or the Secretary of State for Wales. Unless an Order has been made to bring them under control, discharges of water raised from underground mines are exempted from liability for the offence of causing pollution. Although the Acts do not bind the Crown, discharges and outlets from Crown properties (such as hospitals and defence establishments) are expected to conform to the requirements of the river authority. The Clean Rivers (Estuaries and Tidal Waters) Act 1960 brought under control new outlets and discharges to tidal rivers, estuaries and parts of the sea (as specified in the schedule to that Act) if they were first constructed or begun after 29 September 1960 or substantially changed after that date. The control can be extended by order under the 1951 and 1961 Acts to virtually all discharges to particular tidal rivers, estuaries or parts of the sea. So far, orders have been made for only fourteen mostly small estuaries. Full powers of control over the tidal Thames have been exercised since 1968 by the Port of London Authority under local Acts.

4. Discharges subject to control may be made only with the consent of the river authorities who may attach conditions as to the nature and composition, temperature, volume or rate of discharge of the effluent. The decisions of the river authorities on consents and consent conditions are subject to appeal to the Secretaries of State for the Environment and for Wales, respectively.

5. The present system of control of discharges is of comparatively recent origin - pre-1951 discharges to non-tidal rivers and canals were exempt until 1963. The work of determining the actual conditions of consent for the large number of discharges has not yet been entirely completed in some areas. Although there is no statutory minimum standard

which discharges must reach, it has for many years been normal practice to require that discharges of sewage effluent to inland rivers should comply with the standards recommended by the Royal Commission on Sewage Disposal (1898 - 1915), which are a maximum of 30 milligrams per litre (mg/l) suspended solids and 20 mg/l biochemical oxygen demand when the effluent is diluted by clean water of at least eight times its volume. In recent years it has been more common to set standards according to individual circumstances and more restrictive standards have often been imposed, especially where the dilution afforded by the river is small and it is particularly important to maintain a higher standard of purity, for example, in rivers used as sources for public water supply.

6. Under the Public Health (Drainage of Trade Premises) Act 1937 and Public Health Act 1961, manufacturers and farmers may discharge their liquid waste to the public sewers, subject to such conditions and charges as the local sewerage or sewage disposal authority may require. There is a right of appeal to the Secretary of State for the Environment or for Wales against the conditions and the charges for treatment. Because large volumes of trade effluents are not disposed of in this way consents for the discharge of sewage effluents commonly contain restrictions on concentrations of named substances which could be toxic at materially higher concentrations. Direct discharges of trade wastes to controlled rivers are subject to the same controls as discharges of sewage effluent; the river authorities impose consent conditions appropriate to the quantity and character of the discharge and it is the responsibility of the industrial discharger to provide the treatment necessary to meet the required standard.

7. The responsibility for the disposal and treatment of sewage and trade effluent discharged to the sewers is exercised by about 1,400 local authorities, comprising the Greater London Council, the councils of boroughs, urban or rural districts and joint boards of these councils. These authorities are responsible for populations ranging from about 8 million to less than 1,000. Their statutory responsibility for sewage disposal is to make such provision by means of sewage disposal works or otherwise as may be necessary for effectually dealing with the contents

of their sewers (Public Health Act 1936). The local sewage disposal authorities normally provide works for the treatment of sewage before it is discharged to non-tidal rivers but there are still large numbers of outfalls discharging crude sewage to estuaries which are not covered by Tidal Waters Orders. There are now, however, schemes which will improve the major polluted estuaries of the Tyne and the Tees.

8. The Secretaries of State for the Environment and for Wales exercise the central government functions in sewerage and sewage disposal. They have powers to determine appeals, to make regulations and orders under the Public Health Acts, and to intervene when default is alleged on the part of sewerage authorities. They control public capital investment in sewerage and sewage disposal by means of their statutory control over borrowing by local authorities. Schemes costing more than £100,000 or the product of a rate of 1p in the £, whichever is larger, may be examined by a departmental Engineering Inspector. Specific Exchequer grants are only available for first-time sewerage in rural localities, for schemes required for town expansion under the Town Development Act, and for the improvement of an inadequate service in a development or intermediate area under the Local Employment Acts.

9. Many areas, especially towns with long established sewerage systems, are drained on the combined or partially-separate system, with all or part of the surface water from roofs and paved areas carried in the same sewers as foul sewage. Storm overflows then relieve the sewers in time of heavy rainfall by discharging a mixture of untreated sewage and surface water directly to watercourses. Such discharges come under river authority control.

## APPENDIX 2

CONDENSATION OF "PROGRAM FOR THE PROTECTION OF THE ENVIRONMENT", WRITTEN AND ADOPTED BY THE FEDERAL REPUBLIC OF GERMANY

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## CONDENSATION OF "PROGRAM FOR THE PROTECTION OF THE ENVIRONMENT" WRITTEN AND ADOPTED BY THE FEDERAL REPUBLIC OF GERMANY

The following comments summarize the programme.

1. Inadequate efforts were made during the past.
2. The Federal Government appointed a cabinet committee on environmental problems, charged with preparation of the program for the protection of the human environment, in 1969.
3. Due to the gravity of the environmental problem, an immediate action program was established in September, 1970 announcing a parcel of urgent legislative projects which, in the meantime, have been referred to all legislative bodies. During the Bundestag debate on the 16th of December, 1970, the Federal Government stated detailed reasons in support of the need to confer upon the Federation concurrent legislative powers in the fields of water resource management, protection of nature and landscape, air pollution control, abatement of noise and disposal of waste. These new powers will be the only means of achieving the aim of this program.
4. Numerous experts from the administration of the Landers and from the fields of science and industry have participated in the preparation of this program.
5. Summary of Basic Theses Underlying the Environmental Program.

5.1 An environmental policy should comprise the totality of all measures which are necessary to:
- preserve an environment which man needs for his health and for a dignified human existence;
- protect the soil, air and water, animal and plant life against harmful effects of human action; and,
- eliminate any damage or disadvantages arising from such human action.

5.2 The expenditures arising from measures to restore the environment should, as a matter of principle, be borne by the originator of the damage, ("originator principle").

5.3 In implementing this program, the financial capability of the national economy will not be unduly strained. Measures designed to protect the environment are to be supported by action in the fiscal and tax fields as well as by infrastructure measures.

5.4 The state of the environment is largely determined by technology. Technical progress should take place in a manner which is not harmful to the environment. It is one of the objectives of this program to achieve an environment-orientated technology which does not constitute an excessive burden on the environment. This need not affect technological progress or economic growth.

5.5 It is a matter for each individual citizen to help protect his own environment. The Federal Government regards the strengthening of popular environmental consciousness as an essential element of its environmental policy.

5.6 To enable the Federal Government to take the right decisions in questions of the protection of the environment, increasing use will be made of scientific advice. To this end, a Council of Experts on Environmental Problems will be appointed and other measures will be taken.

5.7 The full range of threats to the environment and their effects should be the subject of systematic research work. The capacities of research and development establishments will be expanded as required, and coordination of the relevant research work will be intensified. In addition, it will be necessary to collect all data relevant to the environmental problem and to concentrate and systematize them in an information system which is available to government, the scientific community and industry.

5.8 The possibilities of training in the special fields of the environment are to be improved, among other things by the creation of interdisciplinary and practical courses at universities and technical colleges.

5.9 If the human environment is to be effectively protected, there is a need for close cooperation between the Federal Government and the regional and local authorities as well as between them and the scientific community and industry.

5.10 The protection of the environment also requires international cooperation. The Government of the Federal Republic of Germany is fully prepared to cooperate in all fields and advocates the conclusion of international agreements.

6. The Cabinet Committee for Environmental Problems which sat on July 6, 1970 coordinates the activities of all Federal Departments. It was this committee which drafted the present comprehensive environmental program in close cooperation with the experts from the Regional Administrations, industry and science. The most urgent problems were tackled under the Immediate Action program of September 17, 1970.

7. It is absolutely necessary, according to Federal policy, to create conditions for a long term environmental policy.

8. Where rapid action is called for, i.e. in the fields of waste disposal, sewage treatment and protection against the discharge of dangerous substances, the Federal Government has already introduced those draft laws which are designated to bring about an early improvement of the situation.

9. This program consists of two parts. Part A contains the basic features of a long term environmental policy. Part B, the action program itself, presents all those priority measures which should be implemented or at least initiated within the next five years, broken down by environmental fields. Additional objectives within the next ten to fifteen years are outlined. While part A describes the actual situation and the motives of the Federal Government's environmental policy consideration, Part B draws the conclusion to the extent that they can be practically realized within the existing financial and institutional limits. The objectives are:

9.1 Long-term environmental planning.

9.2 Enforcement of the Originator Principle.

9.3 Achievement of an environment-orientated technology:

- technological developments should take into consideration their effects on the environment; and,
- decisions by public authorities and industry should bear in mind certain environmental criteria.

9.4 Awakening or strengthening an "environmental consciousness" in all parts of the population.

9.5 More effective international cooperation.

10. In order to obtain scientific advice, the Federal Government will appoint a Council of Experts on Environmental Problems which will be set up on January 1, 1972 under the auspices of the Federal Ministry of the Interior. Its members will be chosen by the Federal Minister of the Interior with the agreement of the cabinet committee for environmental questions.

11. The Federal Government has not, up to now, been in possession of the legal basis on which the ecological, economical and financial data of the various environmental threats, and their consequences, can be inexhaustibly and regularly collected. The statistical surveys concerning data relevant to their environment which have already been carried out are to be perfected. The Federal Government will, therefore, introduce a draft law on environmental statistics by the 14th of June, 1972. Working groups for the public sewage system and water supply, substances harmful to water, transport services broken down by region, types and quantities of waste, as well as for air pollutants, have been set up under the Federal Statistical Office. In the long run, the Federal Government intends to compile a meaningful "environmental balance sheet", which will make it possible to identify changes in the quality of the environment regularly and reliably.

12. The term "originator" must be applied to any person or agency which, by using a certain product, lays the basis for later damage to the environment.

However, under the present system of sharing the cost of damage to the environment, the originator principle is largely ignored and this cost is imposed on the community without any reference to the product or service which caused it. This program makes a beginning by providing for a sewerage levying.

13. The Federal Government has appointed a working group to consider procedures and recommendations on how the originator principle can best be enforced.

14. It cannot be primarily a public task to finance environmental protection measures from the tax revenue of the community. The Federal Government proceeds from the principle that the cost involved should be borne by those imposing a burden on the environment, ("originator principle"). If serious environmental damage is to be avoided, it will be, in exceptional cases, necessary to perform certain public functions at below cost prices. In the case of very capital intensive public facilities having a long life, it may be necessary to pre-finance them initially from public funds, or through credit.

A survey of public tasks in the environmental field reveals that the main purpose of public expenditures will be to finance the necessary investments from adequate treatment and waste disposal facilities, which are a matter for local authorities and should be financed by them. According to the division of responsibilities laid down in the federal constitution, it is up to Regional authorities (Landers) to support the local authority in the fulfillment of these tasks within the framework of the redistribution of the tax revenue among the various local authorities. According to the division of responsibilitities and charges undertaken in the Constitution, the Federal Government has only limited administrative and financial competence in the environmental field.

15. The requirements of the environment will have to be taken into account to a greater extent in the redrafting of tax legislation.

16. Harmonization and intensification of the existing tax incentives for investments in the fields of sewage disposal, the purity of the air and the reduction of noise and vibrations should be accomplished, as well as the extension of tax incentives to investments designed to prevent or limit the production of sewage or the absorption of heat by inland waters.

17. At the time of writing of the program, research work is being financially supported in the following fields.

a) equipment for the detection of most important harmful substances in air and water;

b) processes for the purification of industrial, domestic and motor engine exhaust gases, as well as of all polluted waters; and,

c) production processes causing only limited damage to the environment and products entailing less waste.

18. It is considered that the present legislative provisions concerning the protection of nature no longer meet the requirements of the modern industrial society. The German law of 1935 on the Protection of Nature, which continues to be valid law in the Landers, has been changed in an uncoordinated manner by eight Landers. Moreover, the old law is essentially directed towards idealistic aims and the preservation of areas. In order to control the growing restraints on nature, a new law is intended which will ensure that the landscape will be developed and its functions restored.

19. Among the requirements of the new law, the Landers shall draw up regional waste disposal plans which may be made compulsory. Waste disposal shall be the responsibility of authorities such as rural and urban districts, or associations formed for this purpose and designated by the Landers, or they may instruct the owners of industrial waste to dispose of it themselves.

20. It will also be necessary to construct environmental and pilot facilities. This is a Lander responsibility.

21. Water

Overall Situation

The hydrosphere is in disorder. Excessive demands have been made for a long time on the self-purification capability of many waters. This reduces the local value of many areas, but also the recreation value of the landscape. In some places, the lack of clean water begins to slow down economic development. The increasing pollution of the high seas also gives cause for concern.

This dangerous situation can be improved only if an overall concept of water management for the whole area of the Federal Republic of Germany is developed as soon as possible. As part of this effort, it is necessary to amend the existing disorganized and outdated water legislation by uniform provisions adjusted to the requirements

of modern water management. However, even a modern and uniform water law is of no use unless it is consistently applied.

Water Management Law

The Federal Water Management Law which dates back to 1957 must be amended and strengthened.

However, according to valid constitutional law (sub-para 4 of para 1 of Article 75 of the Constitution), the legislative bodies at the Federal level may only enact general provisions in the field of water management. In view of this constitutional limitation, only a few of the necessary amendments to the water management law can be enacted. For the majority of the changes required in the water management law, the Federal legislative bodies are at present not in possession of adequate legislative competence. The Federal Government has therefore introduced a Constitutional Amendment (Parliamentary Records VI/1298) designed to provide full legislative authority to the Federal authorities. However, the Federal Government is not awaiting the adoption of this Amendment, but is preparing for the necessary changes in view of their urgency. At the same time, the legislative bodies are given to understand what use the Federal Government will make of its full authority once it has been granted.

The water management law is to be changed in two stages:

A Fourth Law (Federal Council Records 411/71) amending the water management law will especially

- improve the possibilities to authorize the use of waters only subject to certain conditions;
- lay down uniform Federal provisions for the storage of substances dangerous to water;
- authorize the authority to forbid changes in the use of such water surfaces which are required under the water management plans; and,
- revise the punitive provisions of the law.

The Fifth Law amending the water management law is to authorize the Federal Government

- to lay down uniform standards according to which the quality of a water may be determined so that waters having this or a higher

quality may be preserved while waters of lower quality must be cleaned; and,

- to issue guidelines as to the requirements to be placed on the introduction of sewage into waters.

A further law will provide for the imposition of sewage levies. The Federal Government will introduce the Fifth Amendment to the water management law by 31 July 1972 and the draft law on the imposition of sewage levies by 31 December 1972.

Water Management

In spite of the excessive strains placed on waters in the Federal Republic of Germany, the supply of "clean" water to the population and to industry has up to now been possible. However, this cannot conceal the fact that the accumulated requirements for sewage treatment facilities and sewers is large.

It is the objective of water management to arrive at a hydrospheric balance which ensures that

- the ecological equilibrium of the waters is preserved or restored;
- clean water can be supplied to the population and to industry; and,
- at the same time, all other uses of water serving the common good remain a long-term possibility.

In the opinion of the Federal Government, this aim can best be reached by conferring on the authorities, associations or other agencies which must take or coordinate water management measures the responsibility for a complete river area.

As a result of the insufficient purification of sewage water, the quality of the waters has improved only in isolated cases in spite of all the efforts of the local authorities and industrial enterprises and in spite of the financial support by the regional and Federal authorites. In other cases, however, the water quality has declined to such an extent that certain uses of water are today no longer possible or only at unreasonable expense.

22. It is also considered that the general water management plans call for the construction of an additional number of water reservoirs and rain water collection basins. It may be possible to finance these projects from funds provided under the communal task "improvement of agrarian structure and coastal protection".

23. This is a list of measures having financial implications on the Federal project referring to part B of the program.

23.1 Promotional research and development for the disposal of domestic refuse, unwieldy waste and road sweeping.

23.2 Intensification of the construction of sewage purification facilities in the public domain. Regional and local authorities will have to invest altogether about 10 billion German Marks from 1972 to 1975 for the construction of sewage purification facilities and sewers. To this must be added considerable industrial investment.

23.3 Federal program for the Purification of National and International Waters.

23.4 Creation of a systematic network of water monitoring stations.

23.5 Technical and organizational measures for the creation of compound systems, the protection of water procurement areas, the establishment of large size central water supply facilities, the improvement of treatment techniques, and the drawing up of an emergency well program and alert plans.

23.6 The drawing up of general plans of water management.

23.7 Construction of additional water reservoirs and rain water basins.

23.8 Support of individual research and development projects and water research.

23.9 Expansion of existing and creation of new institutions for the protection of the environment.

23.10 Research and development activities of the relevant Federal institutions, universities and industries, and the contents, distribution and effects of harmful substances in the sea and in marine organisms.

## MINISTERIELLE UND PARLAMENTARISCHE GREMIEN

## FEDERAL AUTHORITIES

Interministerieller Ausschuss Wasser,
Der Bundesminister fur Gesundheitswesen (BMGes)
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Landerarbeltsgemelnschaft Wasser (LAWA)
53 Bonn 9, Bundeshaus, Postfach 9110,
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Telex: Uber 98 86 808

Der Bundesminister fur Ernahrung, Landwirtschaft und Forsten (BML)
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Der Bundesminister fur Gesundheitswesen (BMGes)
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Innenministerium Baden-Wurttemberg,
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Oberste Baubehorde im Bayerlschen Staatsministerium des innern,
Gruppe Wasserbau un Wasserwirtschaft,
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Schleswig-Holstein - Abteilung III 2 - Wasserwirtschaft -
und Landesamt fur Wasserwirtschaft,
23 Kiel, Dusternbrooker Weg 104 - 108,
Tel: 59 61

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## MAIN CONSERVATION AUTHORITIES

Emschergenossenschaft
43 Essen, Kronprinzenstrasse 24,
Tel: 2 33 61

Grosser Erftverband
515 Bergheim/Erft, Pfaffendorfer Weg 42,
Postfach 320,
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Linksniederrheinische Entwasserungs-Genossenschaft (LINEG)
413 Moers/Ndrrh., Augustrastrasse 8,
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Lippeverband
43 Essen, Kronprinzenstrasse 24,
Tel: 2 33 61,
u. 46 Dortmund, Konigswall 29,
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Niersverband
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# APPENDIX 3

## SUMMARIES OF RETURNED QUESTIONNAIRES

QUESTIONNAIRE NO. 1
SEWERAGE FUNDAMENTALS

| SWEDEN | 2<br>Municipal | 3<br>Municipal | 4<br>Municipal | 5<br>Consultant | 6<br>Standards |
|---|---|---|---|---|---|
| 1. Roof Drainage<br>Is residential roof drainage:<br>a) discharged into storm sewers?<br>b) discharged into street gutters or ditches?<br>c) discharged onto property for seepage into soil?<br>d) used for irrigation?<br>e) disposed in some other way? | a) | a) in new developments<br>b) older developments<br>c) seldom | a) | a) | a) & c) |
| 2. Foundation Drains<br>Are these normally connected to:<br>a) storm sewers?<br>b) sanitary sewers?<br>c) combined sewers?<br>d) another disposal system? | b) | a) in new developments<br>b) not permitted<br>c) older developments | a) | b) | b) |
| 3. Cleaning Practices<br>(i) Streets<br>a) Are downtown streets swept/washed daily/weekly/monthly? | Swept 2-5 times/week plus sporadic flushing | Centre swept 4 times/month; rest swept twice/month | Swept daily | Swept or washed monthly | Swept in spring, varies |
| b) Are suburban streets swept/washed daily/weekly/monthly? | Swept once/week, flushing only on main streets | Swept once/month | Swept weekly | Swept or washed monthly | Swept in spring, varies |
| c) How does the frequency of street cleaning depend upon adjacent land use? | | Indirectly | | | |
| d) Are streets cleaned for aesthetic reasons or to improve the quality of runoff? (Is it accepted that the quality of the street runoff is dependent upon the frequency of street cleaning?) | Aesthetic & hygienic reasons | Aesthetic reasons primarily | Aesthetic reasons primarily | Aesthetic & hygienic reasons | Both |
| e) What type of equipment is used for street cleaning? | Power brushes, flushers, handwork for leaves in park | Power brushes, no vacuum cleaners | Power brushes, no vacuum cleaners | Power brushes, no vacuum cleaners | Power brushes & flushers |
| (ii) Sewers<br>a) What is your regular maintenance program for sewers? | | Varies on basis of long term statistical background | 5% flushed every month, some more often, others once /year or not at all | Not done systematically | Study presently underway |
| b) By what methods do you normally clean sewers? | High pressure flushing | 9-16" dia. high pressure flushing, then cleaning machines | High pressure flushing | High pressure flushing | High pressure jetting |
| c) Do you make a practice of flushing sewers during dry weather? | No | No | No | No | No |
| d) Do you install catchbasins for street drainage on new sewers? | Yes | Yes for new storm sewers | Yes | Yes | Yes |
| e) How often and by what method do you clean catchbasins? | | Once/year, suction pumps | Once/year, suction pumps | Twice/year suction pumps | Spring & fall, suction |
| (iii) Snow Removal<br>a) When removing snow from the road or highway, do you plough it to the side and leave it to accumulate and ultimately melt, or do you remove it and dispose of it at a lake/river, sewer/snowdump or other? | Plough & dump in lake, or melt using machines or heated pavements | Plough it to side and leave it unless it interferes with traffic | Plough it to side and leave it unless it interferes with traffic | Plough it to side and leave it unless it interferes with traffic | Plough then tip into lake in Stockholm, heated plazas |
| b) Is the frequency of snow removal determined by any factors other than quality? | Danger to children | Pollution source at times | No | No | |
| c) What equipment is used for snow removal? | Ploughs, trucks, loaders, melting machines | Snow ploughs, trucks, loaders | Snow ploughs, trucks, loaders | Snow ploughs, trucks, loaders, melting machines | |
| d) Has the environmental impact of snow melt water, or content of the de-icing materials or abrasive materials in the snow melt been assessed? Alternatively, has the effect on the treatment plant been assessed in the case of combined sewers? Could you please identify the materials used for de-icing and summarize the result of assessments? | Yes, sodium chloride or potassium chloride depending on temperature range | Sodium chloride | Sodium chloride in very limited use | Sodium chloride or calcium chloride, decreasing amount used | |
| e) Has lead or other heavy metal been identified as a serious snow contaminant? | Yes | Only on highly travelled streets | No | Yes, the last 3-4 years | Yes |
| 4. Control of Infiltration into Sewers<br>a) Are infiltration allowances specified in design manuals or standards? | | Yes, all sanitary sewers are tested for leakage and are inspected | Should be completely free of leakage | Yes | |
| b) What is the policy for infiltration control? | | As above, plus TV inspection and flow measurements | Test for chlorides to determine salt water infiltration | Small amount of infiltration is accepted | Related to TP capacity |
| c) What means are used to correct excessive infiltration? | | Rebuilding bad sections, concrete injection and plastic lining sewer | Rebuilding bad sections, concrete injection and plastic lining sewer | Rebuilding bad sections, concrete injection and plastic lining sewer | Rebuilding bad sections. Manholes found to be major source. Testing procedure established with either air or water |

QUESTIONNAIRE NO. 2
DESIGN PRACTICES OF NEW SEWER SYSTEMS AND
MODIFICATIONS TO EXISTING SYSTEMS

| SWEDEN | 1<br>Federal | 2<br>Municipal | 3<br>Municipal |
|---|---|---|---|
| 1. Storm Sewer Design<br>a) What storm frequency is required to be used for new sewer systems and what storm duration? | Std. lacking. Usually 1 or 2 yr storm, 10 min duration min. Difference small between rains in Sweden, i.e. 10 yr storm 1.7 x 2 yr storm. | 2 yr storm for combined sewers, 1 yr storm for separate systems. New code is being established. | 1 year storm. 10 minute duration |
| b) Is the design storm derived from an intensity/duration/frequency curve? How is the design storm hydrograph derived? | Swedish Met. Institute | | Yes, from 30 yrs of rainfall data |
| c) Is the design storm frequency/intensity varied for residential areas, commercial & industrial areas, culvert capacities for minor roads, major roads & freeways? | No, only runoff factor | | No |
| d) Is the design of new storm sewer systems based only on quantity? | Yes | | Yes |
| e) Is quality considered in the design as well as quantity?<br>(i) Is anything being done about improving runoff quality?<br>(ii) Is storm runoff treatment anticipated?<br>(iii) Is research proceeding into runoff quality & runoff treatment? | (iii) | (ii) it may be necessary for a major new development N. of Stockholm | (i) no<br>(ii) no<br>(iii) yes, heavy metal content |
| f) Is snow melt considered in sizing the sewer pipe? | No | | Yes, in the larger open areas of outer town |
| g) Are new storm sewer systems designed as separate, combined, partially separate or other? Please amplify. | Separate | Separate | Separate |
| h) Are new storm sewer designs based on:<br>(i) open channel or free flow?<br>(ii) pressurized flow?<br>(iii) sewer surcharge allowed but infrequent? | (i) | | (i) normally but<br>(ii) occasionally |
| 2. Storm Runoff Attenuation<br>a) To reduce the rate of storm runoff, is stormwater stored<br>(i) on roofs?<br>(ii) on streets & sidewalks?<br>(iii) on parking lots?<br>(iv) on school grounds?<br>(v) in parks?<br>(vi) in any wall at all? | No | It is anticipated that use of groundwater replenished through percolation will lead to some form of attenuation. | occasionnaly at (i) and (v) |
| b) What measures are mandatory in new significant sized constructions or developments in order to restrict storm runoff flows? | None | | Development cannot proceed without adequate drainage |
| c) Is ponding or use of depression storage or infiltration used to restrict the intensity of storm runoffs? | Consultant Orrje has full scale research underway. | Yes | |
| d) Is it possible to given quantitive assessment of the attennuation required under 2 (a) & (b), either by depth of water or storm frequency? | | | All sewers designed as 1.a) All flow in excess of this is stored. |

| 4<br>Municipal | 5<br>Consultant | 6<br>Standards | 7<br>Research | 8<br>Research |
|---|---|---|---|---|
| 1 year storm duration dependent on area size, but min. 10 min. | 1 year storm duration depends on overland flow time. | 1 to 10 years depending on area type. | | |
| Rainfall observations | Yes | Yes<br>Swedish Meteorological Institute | Yes.<br>Short duration rain information lacking | Arnell developing design storm hydrograph. New intensity duration curves developed for Goteborg. Area distribution under study. |
| No | Not usually | Basically not now (see 1a) | No, runoff factor varied | |
| Yes | Yes | Yes, except City of Stockholm | Generally yes | |
| No | (i) Yes by cleaning streets<br>(ii) Occasionally, by sedimentation<br>(iii) Yes | (i) One case of treating storm water<br>(ii) First flush treatment<br>(iii) Yes | (iii) Research program incorporating air pollution and corrosion of building materials presently under way | (iii) by Mr. P. Malmquist & Mr. G. Svensson. Previous work by P. Lisper. |
| No | No | Summer rain is criterion used in Sweden. Standard exists. | No, but sometimes made oversize, to be safe | |
| Separate | Separate, or partially separate | Separate | Separate, but investigations indicate that storage prior to entering sewer may allow use of combined sewers. | |
| (i) | (i) | (i) | (i) | |
| No | (ii) & (v) | Only in parks, Insurance compensation practice is paid for flooding by sanitary sewers, but not storm sewers. | Roof storage equipment exists, but rarely used. Storage not considered any other way | |
| | None | Rules being developed restrain groundwater lowering, thus restricting storm runoff. | Very little | |
| Limited use | Limited use | Limited use.<br>See above | No, but considered unpopular due to aesthetics & danger to children | |
| | No | No | No | |

| | 1<br>Federal | 2<br>Municipal | 3<br>Municipal |
|---|---|---|---|
| 3. Sanitary Sewer Design<br>a) Are new sanitary sewers designed as gravity sewers, pressurized sewers, combination partly gravity, partly pressurized or as vacuum sewers? | Gravity (and pressurized lines from lift stations) | | Gravity |
| b) Please outline any experience you may have re pressurized sewers or any on going research you are aware of into pressurized sewers. | | | Operation less reliable |
| c) Please specify what sources of sewage drain into sanitary and storm sewers respectively in the case of partially separated sewers. | | | No partially separate; either separate or combined |
| d) How is the maximum capacity of the sewage treatment plant related to the dry weather flow? | Q max = 4 x Q dim. | | Plant capable of treating DWF only. Excess stored. |
| 4. Storm Holding Tanks - Combined Sewers<br>a) Are storm holding tanks generally constructed at sewage treatment plants? | No | | No, storage tunnels used instead. |
| b) How is their volume calculated relative to the capacity of the overflow capacity of the plant? | | | Tunnels dimensioned for flow with additional storage capacity. |
| c) Is the quality of sewage routed to the tank considered in the design of the tank? | | | Tunnel slope considered |
| d) Is provision made for treating the capacity of the storm holding tank:<br>(i) within the tank?<br>(ii) separate treatment plant?<br>(iii) by pumping back to main plant?<br>(iv) is ozone used for the treatment?<br>(v) how much is treated and how is it discharged?<br>(vi) would you please describe the plant and process used for (i) or (ii) or (iv)? | | Attempts should be made to avoid sedimentation in tanks and sewers where possible | Tunnels are aerated |
| e) What is the prime factor limiting the detention period in a storm holding tank?<br>(i) construction costs?<br>(ii) oxygen depletion?<br>(iii) probability of new storm occurrence? Please amplify. | | (i) | (i) dictates wheather tunnel or pipe |
| 5. Storm Runoff Storage<br>a) Is detention storage provided for storm sewers either in-system or off-system, as a single storage structure one cell or multi-cell or as a system of storage structures? | | In-system planned | In-system (tunnels) |
| b) Is detention storage provided in natural depressions or in reservoirs (with embankments), fully enclosed tank above ground, below ground or below water? | | Rock tunnels | Natural depressions of reservoirs, u/g tanks, large sewers |
| c) If not as outlined in 5(a) or (b), by what method is storage provided? | | Storage in existing rock tunnels and in enlargements of these is now planned. | |

| 4<br>Municipal | 5<br>Consultant | 6<br>Standards | 7<br>Research | 8<br>Research |
|---|---|---|---|---|
| Gravity sewers | Gravity, but pressurized & vaccuum in smaller districts | Gravity sewers, exceptions exist. | Gravity but vacuum in special cases | |
| Problems with deposits, surges at pump starts, and with valves | | Stockholm suburb of Balingeby has pressurized system. Report available Construction poor, Expensive. | | |
| | Sanitary sewer-domestic, industrial, foundations. Storm sewer-rainfall, roof drainage | | Few investigations on this subject. One study indicates 50% of sewage in a separate system was other than sanitary. | |
| | 4 x DWF gets mechanical treatment<br>2 x DWF gets chemical & biological treatment | | | |
| No | No | No, but of 77 municipalities, 11 have holding tanks, Size 140 to 180,000 cubic meters. | | |
| | N/A | | N/A | |
| | | | N/A | |
| | | No | | (iv) Goteborg made extensive tests into ozone for their water supply and found that it was absolutely the most expensive way of disinfecting water |
| | | Construction costs | (iii) but lack of rainfall data | |
| Parallel pipe packages | No | Parallel pipe packages used | Parellel pipe packages used as well as tunnel systems | |
| Parallel pipe packages | | | not presently | |
| | | | | |

| | 1<br>Federal | 2<br>Municipal | 3<br>Municipal |
|---|---|---|---|
| 6. What Is Main Criterion Considered in locating Storm Water Storage Structures?<br>a) public acceptance<br>b) land availability<br>c) sewer system capacity<br>d) close to the waste treatment plant<br>e) other (please specify) | | | (c) and (a) |
| 7. Treatment of Storm Runoff and Overflows<br>a) Combined Sewers<br>Is treatment of storm runoff and/or overflows:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered? What equipment is used? | (iv) Screening<br>Straining<br>Sedimentation<br>Disinfection | Straining and disinfection considered but not used. | (iv) |
| b) Storm Sewers<br>Is treatment of Storm Sewers:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered? What equipment is used? | (iv) As above | (iii) Possibly | (iv) |
| 8. Would you please outline operational problems which have arisen with storm runoff storage with respect to solids removal or quality control? | | | No problems arisen -maintenance once per year to remove sludge |
| 9. Field Studies of Sewer Systems<br>a) Field studies carried out to support:<br>(i) design of new sewers (storm or combined)<br>(ii) analysis of existing sewer systems<br>(iii) design of overflow control schemes<br>(iv) other - please specify | | A system is being installed at Jarva to measure quantity and quality of runoff over a long period of time | (ii) and (iii) |
| b) Field studies are not presently anticipated because:<br>(i) sufficient information on sewer system available<br>(ii) mathematical simulation models eliminate the need for above studies.<br>(iii) other - please specity | | | (i) |
| c) In a typical field study the following phenomena are recorded:<br>(i) flow rates<br>(ii) precipitation<br>(iii) water quality<br>(iv) other - please specify | | | (i) (ii) and (iii) |
| For the above please specify most successful equipment and methods used, their accuracy, operational equipment. Are there any data covering all items and available (eventually for different land use)? | | | Presently, weir or Ventura flumes used. Isotope methods may be used in future. Sewage quality continously monitered in treatment plants. |

| 4<br>Municipal | 5<br>Consultant | 6<br>Standards | 7<br>Research | 8<br>Research |
|---|---|---|---|---|
| (c) | | (b) Standards are to be established for detention systems | | |
| No | (iv) Storage Tanks | (iv) | (d) EPA studies further ahead then we are. Treatment appears difficult. Large flow, short time | |
| No | Pilot microstraining plant abandoned. Quality okay, but operational nuisance after rainfall. | See U.S.A. practice | (iv) | |
| | No experience | | | |
| | (iv) to support research | Research followed by this organization. | | |
| | | (iv) Studies indicate manholes major source of infiltration. Limit no. of manholes. | See 7 (a) | |
| | (i) (ii) and (iii) | | (i) (ii) and (iii) | (i), (ii) and (iii). Distribution of precipitation composition of area |
| | | Stockholm consultant Orrje have developed a sternwheeler for use in manholes. Paddles clog frequently. | "Plumatic" rain gauge. Flow measurement equipment from U.S. Geological Survey | Tests made on different types of rain gauges |

QUESTIONNAIRE NO. 3
ABATEMENT AND POLLUTION DUE TO
COMBINED SEWER OVERFLOWS

| SWEDEN | 1<br>Federal | 2<br>Municipal | 3<br>Municipal |
|---|---|---|---|
| 1. Combined Sewer Overflows are Considered:<br>a) major source of pollution<br>b) not significant in relation to others<br>c) not significant for local receiving water<br>Please explain | Now that municipal treatment is quite thorough, relative to others, o/flows usually discharge to closest recipient meaning short term o/flows are of importance. | | (b) but when overflow does occur-(a) |
| 2. Policy re Control of Overflows:<br>a) no policy established<br>b) policy based on discharge standards (concentration & frequencies)<br>c) policy based on water quality and use of receiving waters<br>d) other; Please explain. | (b) | Oxygen discharged to poor recipients through the Atlas Cop co Limnex method or other method being planned for Stockholm lakes. | (c) The Watercourt has established that overflow may not occur until dilution 3 times dry weather flow for primary and 5 times for secondary recipient |
| 3. Combined Sewer Overflow Regulators<br>Regulators are set to discharge at the following flows (as related to the interceptor capacity):<br>a) Static regulators - specify most frequently used, up to what flows?<br>b) Dynamic regulators - describe types used, flows | | | (a) manually adjustable weir<br>(b) occasionally float type rather old<br>Flow proportional to dilution |
| c) Are regulators controlled by overflow quality, what types used, operational experience. | | | No |
| d) Research on overflow regulators - if any. | | | |
| 4. Computer Controlled Systems Maximizing Storage in Combined Sewers:<br>Are any such systems used currently or planned?<br>What is your attitude towards the above system? | No.<br>Cautious. | May be used in future to help planning and development | System planned with Chalmers University but not yet proven |
| 5. Use of Drag Reduction Additives to Increase Sewer Capacities:<br>Are any above additives used or planned to be used?<br>If so, what types are being used or considered?<br>Was impact of additives on waste treatment plant and receiving water evaluated; please specify. | | | "Kloreben" and "Solvex" have have been used very seldom - Solvex also used at treatment plant. |
| 6. Selection of Pollution Abatement Schemes:<br>a) Are any other abatement schemes than the above (i.e. Items 3-5) used?<br>Is any of the above schemes preferred? | | A selection of outfall location to protect poor recipients, beaches and other recreational areas | |
| b) Selection of abatement schemes is done:<br>(i) on the basis of experience, only some promising schemes are considered.<br>(ii) a number of abatement schemes are considered in a computerized analysis based on a simulation model.<br>(iii) a combination of (i) and (ii)<br>Please specify. | | | |

| 4<br>Municipal | 5<br>Consultant | 6<br>Standards | 7<br>Research | 8<br>Research |
|---|---|---|---|---|
| (a) | (a) | (a) Overflow Frequencies have been measured in 7 Swedish cities | (a) | |
| (c) | (c) | (a) Department of Health may complain. | | |
| | (a) -<br>(b) not used<br>Discharge in excess of 3/4 DWF overflowed | (a) Weir<br>(b) None | | |
| | No | | No | |
| | None | | None | |
| No | No | Not yet.<br>Possible for Stockholm. | Not presently used although maximizing program exists | Research re: Unsteady flow in storm drains by Mr. A. Sjoberg |
| | No | No | No | |
| | Separate sewers built | | Storage of storm water possible:-seperation was solution but high cost of treating storm water may preclude separation. | |
| | (i) | | (i) | |

| UNITED KINGDOM | 3<br>Provincial | 5<br>Municipal |
|---|---|---|
| 1. Roof Drainage: Is residential roof drainage:<br>a) discharged into storm sewers?<br>b) discharged into street gutters or ditches?<br>c) discharged onto property for seepage into soil?<br>d) used for irrigation?<br>e) disposed of in some other way? | a) or combined sewer | a) |
| 2. Foundation drains: are these normally connected to:<br>a) storm sewers?<br>b) sanitary sewers?<br>c) combined sewers?<br>d) another disposal system? | d) soakaways | a) |
| 3. Cleaning practices:<br>(i) Streets<br>a) Are downtown streets swept/washed daily/weekly/monthly? | varies | daily |
| b) Are surburban streets swept/washed daily/weekly/monthly? | varies | weekly |
| c) How does the frequency of street cleaning depend upon adjacent land use? | | |
| d) Are streets cleaned for aesthetic reasons or to improve the quality of runoff? (is it accepted that the quality of the street runoff is dependent upon the frequency of street cleaning?) | aesthetics | Both especially when preventing flooding by falling leaves |
| e) What type of equipment is used for street cleaning? | varies | mechanical |
| (ii) Sewers<br>a) What is your regular maintenance program for sewers? | varies | Depends on size. For old sewers maintenance as necessary |
| b) By what methods do you normally clean sewers? | dragging, waterjetting, manually | dragging, waterjetting |
| c) Do you make a practice of flushing sewers during dry weather? | occasionally, by opening river valves | No |
| d) Do you install catchbasins for street drainage on new sewers? | Yes | Yes |
| e) How often and by what method do you clean catchbasins? | varies | suction pump |
| (iii) Snow Removal<br>a) When removing snow from the road or highway, do you plough it to the side and leave it to accumulate and ultimately melt or do you remove it and dispose of it at a lake/river sewer/snowdump or other? | various methods, but not recurring problem | plough to the side and leave it, but infrequent problem |
| b) Is the frequency of snow removal determined by any factors other than quality? | Yes, location | |
| c) What equipment is used for snow removal? | varies | |
| d) Has the environmental impact of snow melt water, or content of the de-icing materials or abrasive materials in the snow melt been assessed? Alternatively, has the effect on the treatment plant been assessed in the case of combined sewers? Could you please identify the materials used for de-icing and summarize the result of the assessments. | No<br>De-icing material-rock salt<br>No special problems due to snow melt water | |
| e) Has lead or other heavy metal been identified as a serious snow contaminant? | No | |
| 4. Control of Infiltration into Sewers<br>a) Are infiltration allowances specified in design manuals or standards? | Not normally | Yes, empirically. |
| b) What is the policy for infiltration control? | No overall policy | small amount of infiltration acceptable |
| c) What means are used to correct excessive infiltration? | Joint sealing or grouting up brick manholes | |

QUESTIONNAIRE NO. 2
DESIGN PRACTICES OF NEW SEWER SYSTEMS AND MODIFICATION TO EXISTING SYSTEMS

UNITED KINGDOM

| | 1<br>Provincial | 2<br>Provincial | 3<br>Provincial |
|---|---|---|---|
| 1. Storm Sewer Design<br>a) What storm frequency is required to be used for new sewer systems and what storm duration? | 1/2 yr. storm duration = overland flow time | | Varies, according to topography, location, risk |
| b) Is the design storm derived from an intensity/duration/frequency curve? How is the design storm hydrograph derived? | Yes-RRL standard hydrograph | Yes | Yes- Bilham intensities |
| c) Is the design storm frequency/intensity varied for residential areas, commercial & industrial areas, culvert capacities for minor roads, major roads & freeways? | Yes | Yes | Yes |
| d) Is the design of new storm sewer systems based only on quantity? | No | Yes | |
| e) Is quality considered in the design as well as quantity?<br>(i) is anything being done about improving runoff quality?<br>(ii) is storm runoff treatment anticipated?<br>(iii) is research proceeding into runoff quality & runoff treatment? | No<br>(i) barely<br>(ii) no<br>(iii) yes | No, in all cases, but oil/grit traps provided if requested | No, except occasional storm to sanitary connections at low flows |
| f) Is snow melt considered in sizing the sewer pipe? | No | No | No |
| g) Are new storm sewer systems designed as separate, combined, partially separate or other? Please amplify. | Separate | Separate | Preferably separate |
| h) Are new storm sewer designs based on:<br>(i) open channel or free flow?<br>(ii) pressurized flow?<br>(iii) sewer surcharge allowed but infrequent? | (i) | (i) | (i) |
| 2. Storm Runoff Attenuation<br>a) To reduce the rate of storm runoff, is storm water stored<br>(i) on roofs?<br>(ii) on streets & sidewalks?<br>(iii) on parking lots?<br>(iv) on school grounds?<br>(v) in parks?<br>(vi) in any wall at all? | Occasionally by balancing tanks | | Occasionally by balancing tanks |
| b) What measures are mandatory in new significant sized constructions or developments in order to restrict storm runoff flows? | None | | None, although limited discharge may be considered in the design |
| c) Is ponding or use of depression storage of infiltration used to restrict the intensity of storm runoffs? | No | | No |
| d) Is it possible to give quantitive assessment of the attenuation required under 2 (a) & (b), either by depth of water or storm frequency? | No | | No |
| 3. Sanitary Sewer Design<br>a) Are new sanitary sewers designed as gravity sewers, pressurized sewers, combination partly gravity, partly pressurized or as vacuum sewers? | Gravity | Gravity, pressurized | Gravity |
| b) Please outline any experience you may have re pressurized sewers or any on going research you are aware of into pressurized sewers. | | | |
| c) Please specify what sources of sewage drain into sanitary and storm sewers respectively in the case of partially separated sewers. | Sanitary sewer-domestic, back of roofs<br>Storm sewer-front of roofs pavement | Sanitary sewer-domestic & trade effluents<br>Storm sewer-storm runoff & approved trade effluents | Sanitary sewer-domestic, back of roofs.<br>Storm sewer-front of roofs pavement |
| d) How is the maximum capacity of the sewage treatment plant related to the dry weather flow? | 3 x DWF for full treatment<br>3-8 x DWF for partial treatment | 3 x DWF for full treatment<br>3-6 x DWF for partial treatment | "Final Report" recommendations |

| 4<br>Provincial | 5<br>Municipal | 6<br>Consultant | 7<br>Consultant | 8<br>Research |
|---|---|---|---|---|
| Small areas-2 yr storm; large areas-5 yr storm; with exception damage risk, 20 yr storm. If Bilham, duration = overland flow time | 2/5 yr storm. Even 50 to 100 yr storms for major flood prevention schemes | 2/5/10 yr storms | 1/5/10 yr storm. Duration equal to or less than overland flow time. | Varies |
| Yes, either RRL standard hydrograph or Bilham intensities | Yes, RRL standard hydrograph | Contact Met. Office | Yes-modified Bilham, locally adjusted | Yes |
| No | Yes, 5 yr storm for built up areas | Yes 10 yr storm downtown areas; 5 yr storm dense residential areas; 2 yr storm less dense residential areas | Yes | Yes |
| Yes | Yes | Yes | | Varies |
| Generally no, except occasional storm & sanitary connections at low flows. In one instance, a primary tank is being constructed to intercept solids from storm runoff | No in all cases | No in all cases, but oil traps occasionally provided u/s of storage tanks on storm systems. Occasionally stored water is aerated. | Polluted storm runoff may be connected to sanitary sewer, or to storm sewer via oil trap. | (i) partly<br>(ii) sedimentation |
| No | No | No | No | Indirectly |
| Separate, but combined in special instances where storm water pollution is probable such as at produce markets | Preferably separate | Separate | Separate | Separate, combined |
| (i) but in tidal conditions pressurized flow at times | (iii) | (i) | (i), (iii) | (i), (iii) |
| No, but detention reservoirs may be provided where occasional flooding does no harm | On roofs and occasionally by balancing tanks for small areas | No, but in new development natural depressions may be utilized to restrict the runoff to that existing before the development was constructed | In parks | No, in all cases |
| None mandatory, but soak aways used occasionally | None mandatory, but development may be delayed until adequate storm drains exist | Developer must adhere to conditions laid down by Provincial Water Authority Effectively, planning permission witheld | Controlled by Provincial Water Authority | |
| No | On small scale only | Yes, in New Town developments | Not often feasible | Rarely |
| Discharge from storage is restricted to an historical limit which determines the storage | No | No | No | Yes |
| Gravity | Gravity | Gravity | Gravity | Gravity |
| Experiments carried out on vacuum sewers indicate dissolved gases are readily liberated | | | | |
| N/A | | Sanitary sewer-domestic, partially treated trade, Storm sewer-storm runoff, fully treated trade | Sanitary sewer-domestic back of roofs Storm sewer-front of roofs pavements | |
| "Final Report" recommendations | Approx. 4 x DWF | 3-4 x DWF | "Final Report" recommendations | 3 x DWF for full treatment 3-6 x DWF for partial treatment |

| | 1<br>Provincial | 2<br>Provincial | 3<br>Provincial |
|---|---|---|---|
| 4. Storm Holding Tanks - Combined Sewers<br>a) Are storm holding tanks generally constructed at sewage treatment plants? | Yes | Yes | Yes |
| b) How is their volume calculated relative to the capacity of the overflow capacity of the plant? | | 15 Igpcd | "Final Report" recommendations |
| c) Is the quality of sewage routed to the tank considered in the design of the tank? | | Yes | Yes |
| d) Is provision made for treating the capacity of the storm holding tank:<br>(i) within the tank?<br>(ii) separate treatment plant?<br>(iii) by pumping back to main plant?<br>(iv) is ozone used for the treatment?<br>(v) how much is treated and how is it discharged?<br>(vi) would you please describe the plant and process used for d(i) or (ii) or (iv). | (i) & (iii) plant varies | (ii) | Total contents of tank heated by (i) then (iii) |
| e) What is the prime factor limiting the detention period in a storm holding tank?<br>(i) construction costs?<br>(ii) oxygen depletion?<br>(iii) probability of new storm occurrence? Please amplify | 2 hours detention to maximum flow given | (i) | (i) but see "Final Report" |
| 5. Storm Runoff Storage<br>a) Is detention storage provided for storm sewers either in-system or off-system, as a single storage structure one cell or multi-cell or as a system of storage structures? | No | | Varies, either at the T.P. or within the system |
| b) Is detention storage provided in natural depressions or in reservoirs (with embankments), fully enclosed tank above ground, below ground or below water? | No | | Varies |
| c) If not as outlined in 5(a) or (b), by what method is storage provided? | | | |
| 6. What is main criterion considered in locating storm water storage structures?<br>a) public acceptance<br>b) land availability<br>c) sewer system capacity<br>d) close to the waste treatment plant<br>e) other (please specify) | c) | | All factors assessed |
| 7. Treatment of Storm Runoff and Overflows<br>a) Combined Sewers<br>Is treatment of storm runoff and/or overflows:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items what treatment processess are considered? What equipment is used? | No | Yes (iii), utilizing mechanically raked screens | Yes, (i) by sedimentation |
| b) Storm Sewers<br>Is treatment of Storm Sewers:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processess are considered? What equipment is used? | No | No | No |
| 8. Would you please outline operational problems which have arisen with storm runoff storage with respect to solids removal or odour control? | | | |

| 4 Provincial | 5 Municipal | 6 Consultant | 7 Consultant | 8 Research |
|---|---|---|---|---|
| Yes | No | Yes | Yes | Not generally |
| 15 Igpcd | N/A | | "Final Report" recommendations | N/A |
| No | N/A | Yes | "Final Report" recommendations | N/A |
| (iii) | N/A | (iii) | as above | N/A |
| (iii) but see "Final report" | N/A | (i) | as above | N/A |
| Off system considered future | No, only in-pipe storage is available | Varies | Varies | |
| Constructed as lake with variable water level. | No | Preferably reservoirs utilizing natural depressions, otherwise enclosed tanks | Varies | |
| | | Sewer size may be increased | | |
| b) this normally being provided by the developer | | Combination of a), b) & c) | All factors assessed | |
| Yes, (iv) utilizing automatically raked screens & sedimentation tanks with scum plates | No-overflows to tidal river | (iv) | (i) control by Provincial Water Authority | |
| As above | | No | | |
| | | | | |
| | | | | |

| | 1 Provincial | 2 Provincial | 3 Provincial |
|---|---|---|---|
| 9. <u>Field Studies of Sewer Systems</u><br>a) Field studies carried out to support:<br>(i) design of new sewers (storm or combined)<br>(ii) analysis of existing sewer systems<br>(iii) design of overflow control schemes<br>(iv) other - please specify | | (ii) & (iii) | (i), (ii) & (iii) |
| b) Field studies are not presently anticipated because:<br>(i) sufficient information on sewer system available<br>(ii) mathematical simulation models eliminate the need for above studies.<br>(iii) other - please specify | | | |
| c) In a typical field study the following phenomena are recorded:<br>(i) flow rates<br>(ii) precipitation<br>(iii) water quality<br>(iv) other - please specify | | (i) & (iii) | (i), (ii) & (iii) |
| For the above please specify most successful equipment and methods used, their accuracy, operation equipment. Are there any data covering all items and available (eventually for different land use)? | | | |

| 4<br>Provincial | 5<br>Municipal | 6<br>Consultant | 7<br>Consultant | 8<br>Research |
|---|---|---|---|---|
| (ii) & (iii) | (i), & (ii) for large schemes | (i), (ii) & (iii) Contact Hydraulics Research Station | | (i), (ii) & (iii) |
| (ii) model devised by RRL | | | | |
| (i), (ii) & (iii) also, inspection of max. flood level after flood | (i) & (ii) | (i) & (ii) | (i), (ii) & (iii) | (i), (ii), (iii) & infiltration & soil moisture content |
| Flow rates-venturi flumes. Precipitation-autographic gauges Water Quality-24 hr. auto sample | Flow rates-Lea Recorders Precipitation-Autographic gauges | | See "Final Report" | Flow rates-Venturi flume. Precipitation-Casella rain gauge in conjunction with Fisher Foster Tape recorder. |

QUESTIONNAIRE NO. 3
ABATEMENT AND POLLUTION DUE TO
COMBINED SEWER OVERFLOWS

UNITED KINGDOM

| | 1 Provincial | 2 Provincial | 3 Provincial |
|---|---|---|---|
| 1. Combined Sewer Overflows are considered:<br>a) major source of pollution<br>b) not significant in relation to others<br>c) not significant for local receiving water<br>Please explain. | a) | Varies, depending on over-flow setting & type and size of recipient. Most polluted overflows occur because of blockages down stream. | a) Heavy storm conditions have resulted in oxygen depletion |
| 2. Policy re control of overflows:<br>a) no policy established<br>b) policy based on discharge standards (con-centrations & frequencies)<br>c) policy based on water quality and use of receiving waters<br>d) other. Please explain | c) | Generally "Final Report" recommendations | d) improve final effluent from sewage works, thus making occasional over-flow discharges tolerable |
| 3. Combined Sewer Overflow Regulators<br>Regulators are set to discharge at the follow-ing flows (as related to the Interceptor) capacity):<br>a) Static regulators - specify most frequently used, up to what flows?<br>b) Dynamic regulators - describe types used, flows? | a) overflow weirs with control pipes<br>b) not used | a) overflow weirs with control pipe, high side weirs with control pipe<br>b) vortex overflows - penstock control<br>Discharge - "Final Report" recommendations | Capacity of existing downstream sewer used in full. |
| c) Are regulators controlled by overflow quality, what types used, operational experience? | No | No | |
| d) Research on overflow regulators - if any | | | |
| 4. Computer Controlled Systems Maximizing Storage in Combined Sewers:<br>Are any such systems used currently or planned?<br>What is your attitude towards the above system? | No | Yes, dependent upon size & type of scheme | No |
| 5. Use of Drag Reducing Additives to Increase Sewer Capabilities:<br>Are any above additives used or planned to be used?<br>If so, what types are being used or considered?<br>Was impact of additives on waste treatment plant and receiving water evaluated, please specify. | No | No | No |
| 6. Selection of Pollution Abatement Schemes:<br>a) Are any other abatement schemes than the above (i.e. Items 1-5) used?<br>Is any of the above schemes preferred? | | Resewering on separate system as development continues | |
| b) Selection of abatement schemes is done:<br>(i) on the basis of experience, only some promising schemes are considered<br>(ii) a number of abatement schemes are con-sidered in a computerized analysis based on a simulation model<br>(iii) a combination of (i) and (iii) Please specify | | (i) | |

| 4 Provincial | 5 Municipal | 6 Consultant | 7 Consultant | 8 Research |
|---|---|---|---|---|
| If working satisfactorily c), but many operate prematurely due to blockages | a) but b) or c) in tidal waters | b) | Significant source of pollution | b) |
| b), c) | b) but controlled by Provincial Water Authority. | "Final Report" recommendations | "Final Report" recommendations | b), c) |
| a) - b) occasionally used at T.P. Discharge - normally "Final Report" recommendations, but many operate at 30 x DWF or 50 x DWF | a) Storage o/f set at 6 DWF b) - Discharge-"Final Report" recommendations | | "Final Report" recommendations | |
| | | | No | |
| See "Final Report" | | | See "Final Report" and CIRIA | |
| No, suggest overflow structure built to maximum storage | | | Planned | |
| No | Polymer additives are being investigated | No | No | No |
| No | | | | |
| (i) | | | | |

QUESTIONNAIRE NO. 1
SEWERAGE FUNDAMENTALS
GERMANY

| | 4<br>Municipal | 5<br>Municipal | 6<br>Municipal |
|---|---|---|---|
| 1. Roof Drainage: Is residential roof drainage<br>a) discharged into storm sewers?<br>b) discharged into street gutters or ditch<br>c) discharged onto property for seepage in soil?<br>d) used for irrigation?<br>e) disposed of in some other way? | a), b) & c) | a) | c) Combined sewer |
| 2. Foundation Drains: Are these normally connected to:<br>a) storm sewers?<br>b) sanitary sewers?<br>c) combined sewers?<br>d) another disposal system? | a) | a) | a) or c) |
| 3. Cleaning Practices:<br>(i) Streets<br>a) Are downtown streets swept/washed daily/weekly/monthly? | | 2, 3 or 5 times weekly, swept | Swept weekly |
| b) Are surburban streets swept/washed daily/weekly/monthly? | | Swept weekly | Swept weekly |
| c) How does the frequency of street cleaning depend upon adjacent land use? | | No, on condition of street. Usually dependent on the traffic | |
| d) Are streets cleaned for aesthetic reasons or to improve the quality of runoff? (is it accepted that the quality of the street runoff is dependent upon the frequency of street cleaning?) | | Sanitary reasons | |
| e) What type of equipment is used for street cleaning? | | Sweepers | Sweepers |
| (ii) Sewers<br>a) What is your regular maintenance program for sewers? | Yes | None | Control after importance of street. From once per 2 weeks to 2-3 times per year on suburban sewers |
| b) By what methods do you normally clean sewers? | a) high pressure flushing<br>b) cleaning machine<br>c) cleaning shield<br>d) flushing | High pressure flushing | High pressure flushing |
| c) Do you make a practice of flushing sewers during dry weather? | | No | No |
| d) Do you install catchbasins for street drainage on new sewers? | Yes | Yes | Yes |
| e) How often and by what method do you clean catch basins? | | Suction, twice a year approximately | Suction, 3-4 times per year |
| (iii) Snow Removal<br>a) When removing snow from the road or highway, do you plough it to the side and leave it to accumulate and ultimately melt or do you remove it and dispose of it at a lake/river sewer/snowdump or other? | | Ploughed to side of road or removed from city centre | Depends on street importance |
| b) Is the frequency of snow removal determined by any factors other than quality? | | No | |
| c) What equipment is used for snow removal? | | Basically, ploughs | |
| d) Has the environmental impact of snow melt water, or content of the de-icing materials or abrasive materials in the snow melt been assessed? Alternatively, has the effect on the treatment plant been assessed in the case of combined sewers? Could you please identify the materials used for de-icing and summarize the result of the assessments | Limited use of salt | No | |
| e) Has lead or other heavy metal been identified as a serious snow contaminant? | No | No | |
| 4. Control of Infiltration into Sewers<br>a) Are infiltration allowances specified in design manuals or standards? | | No | |
| b) What is the policy for infiltration control? | | | |
| c) What means are used to correct excessive infiltration? | | Good inspection during construction | |

| 7 Consultant |
|---|
| a) or b) |
| a) or c) |
| Swept weekly |
| Swept bi-monthly |
| |
| Aesthetic reasons (yes) |
| Sweepers |
| |
| High pressure flushing or cleaning shield |
| Only if clogging possible 3-4 times per year |
| Yes |
| Suction, 1-2 times per year |
| Usually no problem with snow |
| No |
| Ploughs |
| No planned studies |
| |
| Foreign water content equals dry weather flow mainly due to wrong connections. |
| No problem new developments. Wrong connection in older developments very bad. |
| Strict inspection in new developments. Relining or reconstruction in old areas if bad. |

QUESTIONNAIRE NO. 2
DESIGN PRACTICES OF NEW SEWER SYSTEMS AND MODIFICATIONS TO EXISTING SYSTEMS

| GERMANY | 1<br>Provincial | 2<br>Provincial | 3<br>Provincial |
|---|---|---|---|
| 1. Storm Sewer Design<br>a) What storm frequency is required to be used for new sewer systems and what storm duration? | Usually 1 yr storm<br>densely pop. areas 1 yr<br>sparsely pop. areas 0.5 yr<br>duration: 15 min. | Reinholds method used, but not recommended for municipalities over 5,000 pop. Lower intensity is used in the capital. | 1 yr storm<br>15 min. duration |
| b) Is the design storm derived from an intensity/duration/frequency curve? How is the design storm hydrograph derived? | $Q_t$ = rFY<br>r = intensity (110 l/s.ha)<br>F = area<br>Y = runoff factor<br>(varies 0.1 - 1.0) | If a rain other than the 15 min. desired, it is computed with Reinholds formula | Long term measurements by Met office. Design storm 135 litre sec hectare |
| c) Is the design storm frequency/intensity varied for residential areas, commercial & industrial areas, culvert capacities for minor roads, major roads & freeways? | It can be done but is not usually | No | Usually not, except at critical locations |
| d) Is the design of new storm sewer systems based only on quantity? | Yes | Usually yes. But in the case of the capital, it has been computed in accordance with "Fullhohen ganglinien Method" (Dorsch) | Yes including infiltration of groundwater |
| e) Is quality considered in the design as well as quantity?<br>(i) Is anything being done about improving runoff quality?<br>(ii) Is storm runoff treatment anticipated?<br>(iii) Is research proceeding into runoff quality & runoff treatment? | Generally not, but under some circumstances possible | No | i) 1 + 9 storm water transported to DW where mechanical & biological treatment takes place<br>ii) Not yet |
| f) Is snow melt considered in sizing the sewer pipe? | No | No | No |
| g) Are new storm sewer systems designed as separate, combined, partially separate or other? Please amplify. | Usually combined, but separate in some cases, such as in areas subject to flooding, flat areas & at poor quality recipients | Usually combined, but exceptions exist | Generally combined but separate for areas with poor recipients |
| h) Are new storm sewer designs based on:<br>(i) open channel or free flow?<br>(ii) pressurized flow?<br>(iii) sewer surcharge allowed but infrequent? | i) | i) but during some storms the systems will be pressurized | i)<br>iii) if no damage to the connected houses is inherent |
| 2. Storm Runoff Attenuation<br>a) To reduce the rate of storm runoff, is storm water stored<br>(i) on roofs?<br>(ii) on streets & sidewalks?<br>(iii) on parking lots?<br>(iv) on school grounds?<br>(v) in parks?<br>(vi) in any wall at all? | No except in storm holding tanks | No except in storm holding tanks | (i) No<br>(ii) Natural delay until it runs into catchbasins<br>(iii) & (iv) No<br>(v) Not intentionally<br>(vi) Storm holding tanks |
| b) What measures are mandatory in new significant sized constructions or developments in order to restrict storm runoff flows? | None | Usually none | Construct storm tanks to reduce pollution if recipient is poor |
| c) Is ponding or use of depression storage or infiltration used to restrict the intensity of storm runoffs? | No | Natural features are considered in determining the runoff factor | Only when not used for urban development |
| d) Is it possible to given quantitive assessment of the attenuation required under 2 (a) & (b), either by depth of water or storm frequency? | No | No | No |

| 4 Municipal | 5 Municipal | 6 Municipal | 7 Consultant | 8 Consultant |
|---|---|---|---|---|
| 3 yr storm 20 min. duration 80 litres/sec/hectare | 1 yr storm 15 min duration | 1 to 2 yr storm 15 min duration 100 litres/sec/hectare | 1 yr storm, but storm tanks etc. up to 25 yr duration according to Reinhold. | 1 yr storm, 15 min duration City areas up to 5 yr duration varies according to size, shape & slope of area. |
| Met office continuing measurements to verify existing values | No | Reinold | Depends on computation method. Reinhold constant value. Hydrograph variable intensity. | Yes, for conventional computations. For simulation models several synthetic storms may be used, but derived from I.D.F. curves |
| | No | | Yes, based on probable damage. No fixed rules, usually 1 yr storm. Elbe tunnel 50 yr storm | Yes |
| | Yes | Yes | Yes | Yes |
| No | No | No | (i) No (ii) Not within a foreseeable future. (iii) Tests beginning/75 | (i) Indirectly through design specifications (ii) Yes, allowance at TP for storage or treatment (iii) Publication by Pecher & Lautrich |
| No | No | No | No | No, only where large snowfalls occur |
| Separate | Separate | Combined | New construction, separate First flush to TP considered, but problem of flow directing unsolved. | Separate where storm runoff pollution is low, e.g. suburban areas. Combined system for other, plus city cores. |
| i) | i) | i) | Full sewer flow, since city flat and system submerged | (iii) |
| No | No, except in storm holding tanks | No, except in storm holding tanks | No, except storm holding tanks and the use of oversized pipes, and use of overflow weirs | No |
| None | Construct storm holding tanks | | None, but sometimes storm holding tanks are constructed | None, but sometimes storm holding tanks are constructed. |
| No | No | | No, except at the new city Walfen | No |
| | No | | No | No |

| 9<br>Consultant | 10<br>Standards | 11<br>Research | 12<br>Research |
|---|---|---|---|
| 1 yr storm.<br>15 min duration | | 2 yr storm to 0.67 yr storm dependent on pop. density. Duration 5/15 min dependent on shape of topography | 1 yr storm or 5 yr in special cases. Usually 15 min duration, except in large networks. |
| Met office | | Seldom by local I.D.F. curves. Usually Reinhold and ATV publication 7/1956 "Guidelines for the Design of Storm and Combined Sewers" | Design storm hydrograph derived from 10 to 20 storms using a simulation model. |
| Yes | | Yes | Yes, dependent on risk or extent of possible damage |
| No | | Yes | Yes |
| (i) No<br>(ii) Often space reserved<br>(iii) No | (i), (ii) and (iii) | After the new regulations | Only by specifying dilutions content (1 + 4) or critical rainfall. Eventually simulation models will be developed giving direct information about the effect on the recipient |
| No | Usually not | No | No, only for small mountain communities |
| Mostly combined systems | Trend toward combined systems | Generally combined, but depends on type & location of recipient. New regulations require treatment for storm runoff from new networks. | Separate system if limited pollution load and good recipients. Combined systems for other areas, especially in city centre. |
| (iii) | (i) | (i) | (i) |
| No, except in storm holding tanks. | (v) | Holding tanks located in natural depressions and artificial ponds | Storm holding tanks |
| Construct storm holding tanks | None mandatory, but interlocking concrete blocks may be used instead of impervious pavements. Concern about oil infiltration to groundwater | Often the determination of the largest overflow | Usually none |
| Yes | No, but it may be since groundwater lowering is becoming a problem | Yes, if practical | No |
| Flooding for a maximum of 5 to 20 minutes | | No | Roofs 60 seconds<br>Streets 30 seconds |

| | 1 Provincial | 2 Provincial | 3 Provincial |
|---|---|---|---|
| 3. Sanitary Sewer Design<br>a) Are new sanitary sewers designed as gravity sewers, pressurized sewers, combination partly gravity, partly pressurized or as vacuum sewers? | Gravity sewers | Gravity sewers. Vacuum sewer has been considered for one location | Gravity, 200 litres per person per day. Pressurized sewers only under special conditions |
| b) Would you please outline any experience you may have re pressurized sewers or any on going research you are aware of into pressurized sewers? | Insufficient experience available | No experience | No |
| c) Would you please specify what sources of sewage drain into sanitary and storm sewers respectively in the case of partially separated sewers? | For separation of a comb. system up to Qs sanitary sewer, remainder storm sewer | Sewage to sanitary sewer Stormwater, roof drainage unpolluted cooling water & certain industrial water to storm drain. | The storm sewer should only take street and groundwater. All other types of runoff goes into sanitary. |
| d) How is the maximum capacity of the sewage treatment plant related to the dry weather flow? | 2 to 5 times the dry weather flow | Biolog. 2-3 times $Q_{dry}$<br>Mechan. 5 times $Q_{dry}$.<br>Many plants 10 times $Q_{dry}$ capacity for 15-25 min. detention. | 2 times $Q_{dry}$ for biological treatment |
| 4. Storm Holding Tanks - Combined Sewers<br>a) Are storm holding tanks generally constructed at sewage treatment plants? | Yes | Yes | Yes |
| b) How is their volume calculated relative to the capacity of the overflow capacity of the plant? | $V=(Q_u-Q_{klar})$ t where<br>$Q_u$=max combined sewage flow to TP ($1.2 \times Q_{crit}$)<br>$Q_{klar}$=mech. capacity of TP<br>t = detention time. | $V=(Q_u-Q_{klar})$ t where<br>$Q_u$=max combined sewage flow to TP ($1.2 \times Q_{crit}$)<br>$Q_{klar}$=mech. capacity of TP<br>t = detention time. | 15-20 minute detention period |
| c) Is the quality of sewage routed to the tank considered in the design of the tank? | Usually not | Usually not | Quality of outlet waters total pollution minus 30% |
| d) Is provision made for treating the capacity of the storm holding tank:<br>(i) within the tank?<br>(ii) separate treatment plant?<br>(iii) by pumping back to main plant?<br>(iv) is ozone used for the treatment?<br>(v) how much is treated and how is it discharged?<br>(vi) would you please describe the plant and process used for d(i) or (ii) or (iv). | (iv) No<br>(v) See 6a | (iii) Sludge only<br>(iv) No<br>(v) See 3d<br>(vi) Several methods and processes available | (ii) No<br>(iii) Combined flow below weir to plant<br>(iv) No<br>(v) 10 x Q dry mechanical<br>2 x Q dry biological |
| e) What is the prime factor limiting the detention period in a storm holding tank?<br>(i) construction costs?<br>(ii) oxygen depletion?<br>(iii) probability of new storm occurrence? Please amplify | (i) | (i) | Size of tank and the availability of land |
| 5. Storm Runoff Storage<br>a) Is detention storage provided for storm sewers either in-system or off-system, as a single storage structure one cell or multi-cell or as a system of storage structures? | All three systems are used depending on conditions at site | 1) In a row<br>2) One cell<br>3) Physical properties of municipality | In a row |
| b) Is detention storage provided in natural depressions or in reservoirs (with embankments), fully enclosed tank above ground, below ground or below water? | As above | 1) When possible<br>2) When nothing else possible<br>3) Because of high constr. cost, usually not | 1) When possible<br>2) When nothing else possible<br>3) Because of high constr. cost, usually not |
| c) If not as outlined in 5(a) or (b), by what method is storage provided? | | | In system, provided sufficient capacity exists without harm to the serviced population |

| 4<br>Municipal | 5<br>Municipal | 6<br>Municipal | 7<br>Consultant | 8<br>Consultant |
|---|---|---|---|---|
| Gravity Sewers | Gravity Sewers | Pressure sewers | 80% of trunk sewers have gravity flow. Then partly gravity, partly submerged. | Generally gravity |
| Pressure sewers used for 100 years. 420 Km total length. Pressure to 6 bars. D.I., A.C., & cement lined steel pipes used. | No | | Allowed, subject to City approval. | Allowed, subject to City approval. |
| Sewage only in sanitary. Stormwater only in storm systems. | No | | | Only sanitary sewage in sanitary pipe. |
| 2 x $Q_{dry}$ | Depends on treatment degree & age of treatment plant | | In favourable conditions 1:1.5 | Mechanical treatment 1:25 to 7. Biological treatment 1:1 |
| Yes | Not since separate system used | | No, except at 1 treatment plant | Yes, or space made available |
| 20 minute detention period | | ATV standards | | Varies |
| No | | | | No |
| (i) Yes<br>(ii) -<br>(iii) Yes<br>(iv) No | | | | (iii) |
| (i) | | | (i) | (i) |
| Planned for combined systems. One cell. | All three systems depending on site conditions | | Depends on site conditions mostly one or more cells | All systems used |
| For combined system in fully enclosed tanks below ground or below water | Any of first 3 alternatives | Natural depressions | In reservoirs or enclosed underground tanks, often below water | Depends on hydraulics and locality |
| | | | Detention pipes with weir or throttling device. | Backwater storage system using weir or throttling device. |

| 9<br>Consultant | 10<br>Standards | 11<br>Research | 12<br>Research |
|---|---|---|---|
| Gravity sewers | Gravity sewers | Gravity sewers | Gravity sewers, or pressurized sewers but the latter can be wrong in certain cases. |
| Article in "Wasser und Boden" by Prof. Tiedt, University of Darnstadt. | | | |
| No sanitary sewage in storm water system | | N/A | Basically no sanitary sewage should go into the storm system. |
| Approximately 2.5 to 5 times the dry weather | No 100% correct answer. The proposed 1:7 ratio considered nonsense | Mech treatment $\frac{(1+4)Qdw}{1Qdw}$<br>Biological treatment $\frac{(1+1)\ Qdw}{1\ Qdw}$ | Mech treatment 1 + 4 to 1 + 7<br>Bio. treatment 1 + 1 then aid storm tanks. Mech. treatment beyond 1 + 7 not practical hydraulically |
| Yes | Often | This is a question of process safety and the minimum requirement of the regulatory authority (Provincial) | Only when recipient is overloaded. Space is usually provided at TP for holding tanks |
| Varies | | After the shortest detention period possible and topographic criteria. | |
| No | | Seldom | |
| | (i), (ii) & (iii) Yes<br>(iv), No<br>(v) Old law, not strictly enforced, req. max. of 25 ppm BOD for TP effluent, New law proposes gradual decrease in COD, 80-40-15-0 for storm water. | Usually by pumping back to the plant, but also dependent on operational experience (Sedimentation in system) therefore sometimes within the tank. | |
| | Treatment | (i) | (i) |
| Usually one or more separate cells | | In a row | Depends on hydraulic maintenance and cost criteria |
| Enclosed underground tanks | | Natural depression mostly but can depend on locality | Natural depressions mostly, but can depend on locality and costs |
| | | In enclosed storage tanks in areas of dense popl. Also large dia. pipes (Bonn) or closed in basins | "In-pipe" storage |

| | 1 Provincial | 2 Provincial | 3 Provincial |
|---|---|---|---|
| 6. What is main criterion considered in locating storm water storage structures?<br>a) public acceptance<br>b) land availability<br>c) sewer system capacity<br>d) close to the waste treatment plant<br>e) other (please specify) | Main criteria for<br>a) Limited construction areas<br>b) Basic requirement<br>c) In large networks to<br>d) In small networks | a), b) and c) | a) to d) have to be considdred from case to case. Important that water supply available for periodic cleaning. |
| 7. Treatment of Storm Runoff and Overflows<br>a) Combined Sewers<br>Is treatment of storm runoff and/or overflows:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered? What equipment is used? | Overflows usually not treated. Could possibly be considered for some areas | (i) No<br>(ii) No<br>(iii) No<br>(iv) Yes<br>Numerous German literature available | (i) to (iii) No, (iv) Yes. If storm tank remote from T.P., primary treatment only, unless runoff conveyed to T.P. after storage |
| b) Storm Sewers<br>Is treatment of storm sewers:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered? What equipment is used? | As above | | (i) to (iii) No (iv) In this province only one city has a separate system. Even so it does not function properly. |
| 8. Would you please outline operational problems which have arisen with storm runoff storage with respect to solids removal or odour control? | Deposition of solids & odours occur. Solution by a) scrapers and b) design of base slab to prevent deposition | | It must be possible to remove sediments regularly from storage tanks |
| 9. Field Studies of Sewer Systems<br>a) Field studies carried out to support:<br>(i) design of new sewers (storm or combined)<br>(ii) analysis of existing sewer systems<br>(iii) design of overflow control schemes<br>(iv) other - please specify | (iv) 1) In special cases test quality<br>2) Control of regulators (Weirs, valves, etc.) | (i) only for new areas<br>(ii) So far only in Mainz<br>(iii) No<br>(iv) - | No |
| b) Field studies are not presently anticipated because:<br>(i) sufficient information on sewer system available.<br>(ii) mathematical simulation models eliminate the need for above studies.<br>(iii) other - please specify. | | (iii) Lack of personnel and money | At present many treatment plants should be constructed to clean the combined sewer water |
| c) In a typical field study the following phenomena are recorded:<br>(i) flow rates<br>(ii) precipitation<br>(iii) water quality<br>(iv) other - please specify | (i) and (iii) These programs are carried out to determine cost distribution for construction & operation of treatment plants in industrial areas | | |
| For the above please specify most successful equipment and methods used, their accuracy, operational equipment. Are there any data covering all items and available (eventually for different land use)? | Venturimeters provide satisfactory tolerance. Experience lacking for inductive measuring devices | | |

| 4 Municipal | 5 Municipal | 6 Municipal | 7 Consultant | 8 Consultant |
|---|---|---|---|---|
| | b) and c) | c) | b) and c) | a), b) and c) |
| Partially in the holding tank.<br>(ii) Yes<br>(iii) More are planned | No | (iii) and (iv) | Only one overflow is treated | (iii) Mechanical treatment and recirculation to treatment plant |
| (i) Usually not | No | | No | No |
| | | | To be investigated 1975 | Difficult to design tank with efficient sludge removal |
| (i), (ii) and (iii) | | | (i), (ii) & (iii)<br>(iv) To establish the mathematical models reliability | (iv) Calibration of simulation models and improving models |
| | Not anticipated | (i) | | (iii) Lack of money. |
| (i), (ii), and (iii) | | | (i) and (ii)<br>(iv) Deposition of solids | (i), (ii) and (iii) |
| | | | Due to backwatering, flow measured by level difference between two points using ball gauges, or current meters. | Flow measurements as in answer in Col. No 7<br>Accuracy within 10% |

| 9 Consultant | 10 Standards | 11 Research | 12 Research |
|---|---|---|---|
| b) and c) | b) and c) | c) | a), b) and c) |
| (iii) | (ii) as of next year if law is passed | (ii) In order to decrease maintenance cost tanks with automatic scrapers and high pressure jets for cleaning the base | |
| | (ii) as of next year if law is passed | (ii) | |
| | Avoid sedimentation and associated digestion. See ATV publication A 117 | To be investigated by university for open storage ponds in expanding areas | Important to provide for easy cleaning. |
| (iv) Occurence of foreign water | (i) and (ii partially (iii) | (i) and (ii) Also to determine expansion possibilities | No measurements made by us. When made, they are to further our knowledge and to calibrate simulation models. |
| (iii) Costs | | (iii) Field studies are not always carried out because the construction small TPs often preferable to major reswering schemes | Measurements only give surface runoff and quality data. This data superfluous to practising Engineer, merely confirming design criteria. |
| (i) | (i), (ii), and (iii) | (i), (ii) and (iii) Research project underway, or stormwater quality by this university. Results available, 1975-76 | (i) and (ii), possibly (iii). (iv) Type of areas and topography. Soil moisture content |
| | | Experience not yet determined. 1975-76 | |

QUESTIONNAIRE NO. 3
ABATEMENT AND POLLUTION DUE TO
COMBINED SEWER OVERFLOWS

| GERMANY | 1<br>Provincial | 2<br>Provincial | 3<br>Provincial |
|---|---|---|---|
| 1. Combined Sewer Overflows are considered:<br>a) major source of pollution?<br>b) not significant in relation to others?<br>c) not significant for local receiving water?<br>Please explain | c) | b) | c) |
| 2. Policy re control of overflows:<br>a) no policy established<br>b) policy based on discharge standards (concentrations & frequencies)<br>c) policy based on water quality and use of receiving waters<br>d) other Please explain. | Presently: Design stds. (Wortungskontrollen) | One has to differentiate between design & control of overflows. Policy for the control does not exist. For design the ATV publication is recognized as the standard | a) |
| 3. Combined Sewer Overflow Regulators<br>Regulators are set to discharge at the following flows (as related to the Interceptor capacity):<br>a) Static regulators - specify most frequently used, up to what flows?<br>b) Dynamic regulators - describe types used, flows | Height of overflow weir usually more than 25 cm. Also dependent on critical flow. Static regulators usually used. | The height of the weir can not be related to interceptor capacity, but to the critical flow in relation to the weir length & height, before the overflow begins, Reference ATV. Static regulators of concrete or in some cases wood. | Overflow weir height is dependent on length of the weir and flow. Made of metal "logs", with channel profile |
| c) Are regulators controlled by overflow quality, what types used, operational experience? | | | No |
| d) Research on overflow regulators - if any | No | | No |
| 4. Computer Controlled Systems Maximizing Storage In Combined Sewers<br>Are any such systems used currently or planned?<br>What is your attitude towards the above system? | Not planned | Research in the last few years appear to indicate that this will be possible but we have no practical experience with this yet. | No |
| 5. Use of Drag Reducing Additives to Increase Sewer Capacities:<br>Are any above additives used or planned to be used?<br>If so, what types are being used or considered?<br>Was impact of additives on waste treatment plant and receiving water evaluated, please specify. | No | No | No |
| 6. Selection of Pollution Abatement Schemes:<br>a) Are any other abatement schemes than the above (i.e. Items 1-5) used?<br>Is any of the above schemes preferred? | Increase in overflow dilution rate planned (e.g. 1 to 10) to improve receiving waters See Ref. | No | Static regulators preferred |
| b) Selection of abatement schemes is done:<br>(i) on the basis of experience, only some promising schemes are considered<br>(ii) a number of abatement schemes are considered in a computerized analysis based on a simulation model<br>(iii) a combination of (i) and (ii) Please specify. | | | |

| 4<br>Municipal | 5<br>Municipal | 6<br>Municipal | 7<br>Consultant | 8<br>Consultant |
|---|---|---|---|---|
| Depends on recipient quality. | b) | c) | a) | a) |
| b) | a) | c) | b) Recipient quality criteria to be estabii-shed. An ecological model is planned | Old policy based on dilution New policy based on critical rain intensi-ty, modified by several factors. Also water quali-ty modelling commencing in USA & Hamburg |
| Depends on the degree of dilution | a) 1:9 to 1:13 $Q_{dry}$<br>b) Not used | Depends on recipient quality | | a) see column No. 1<br>b) Preliminary study only |
| Yes | | | Planned, but limited by inadequate rainfall data. Used for first flush in-terception, scouring & optimal storage. | No |
| | | | Minneapolis-St. Paul, Detroit, Cleveland, Seattle, San Francisco, also planned for Hamburg in connection with inverted syphons. | Research beginning in Hamburg |
| No use for such a system since it leads to deposition in sewers. | | | | Planned but system behaviour & increased equipment reli-ability to be proven. Water elevation recorders required. |
| | No | | | |
| Construction of combined sewer clarification tanks. | No | | Research Underway | |
| | | | (ii) | Usually (i), (ii) for special cases |

| 9<br>Consultant | 10<br>Standards | 11<br>Research | 12<br>Research |
|---|---|---|---|
| b) | a) | a) | a) Importance increases the higher the treatment plant capacity. Temporary pollution because of considerable shock loads. |
| c)<br>d) According to Provincial Ministry of the Interior. | b) and e) being established. Presently strong development. Policy should be low in 1 - 2 years | c) References. Vorlaufige Richtlinein fur die Bemessung und Gestaltung von Regenuberlaufen in Mischwasserkanalen. 1:8 to 1:11 dilution of dry weather flow. | The allowable pollution load &/or r crit should be criteria. Ideally allowable yearly avg. BOD should be established for DWF & overflow conditions. |
| Discharge at different flows. No experience with dynamic regulators | Research and test taking place now. | $P_o = 0.7D_o$<br>$P_o$ = Height of the fixed weir over the pipe invert with pipe diameter Do. No upper limit on flows. No dynamic regulator limitations. | Depends on hydraulics, r crit 10-15 litres/sec ha. Min height 25 cm. Dynamic regulators should be avoided from maintenance point of view. |
| No experience | | | This sounds as if it should be full of problems. Only after quantity. |
| No | | No | No |
| No experience | | See column 7. Opinion only useful for large flat cities. Gauges etc., very susceptible to interference, meaning much maintenance | To date, no convincing examples. Differentiate between design & operations. Design useful for large systems. Operation becomes a matter of costs |
| No | No | No | No |
| | | Provincial authorities prefer sufficient dilution of sanitary sewage so as not to endanger recipient. Additionally storm tanks constructed. | No |
| | | | One should consider (ii) but not forget previous experience. Simulation models have the disadvantage that the input criteria is not completely known (design storm). More data has to be accumulated. |

QUESTIONNAIRE NO. 1
SEWERAGE FUNDAMENTALS

| FRANCE | 1 Government | 2 Ministry of Agriculture Local Office | 3 Ministry of Equipment Local Office | 4 Environmental Secretariat |
|---|---|---|---|---|
| 1. Roof Drainage: Is residential roof drainage: a) discharged into storm sewers? b) discharged into street gutters or ditches? c) discharged onto property for seepage into soil? d) used for irrigation? e) disposed of in some other way? | | a) if it exists b) if not | a) industrial areas b) residential areas | a) or b): c) if there is no slope and the ground is permeable. Also depends on the importance of runoff; In separate systems it is better to have surface runoff over as large a period as possible |
| 2. Foundation drains: Are these normally connected to: a) storm sewers? b) sanitary sewers? c) combined sewers? d) another disposal system? | b) Exists in "Pseudo" Separate systems. | a) & c) possibly into ditches or soak aways | a), b) & c) due to multiplexity of systems in older areas now under one authority. | a) or c) depending on the installed system |
| 3. Cleaning practices: (i) Streets a) Are downtown streets swept/washed daily/weekly/monthly? b) Are surburban streets swept/washed daily/weekly/monthly? | | Depends on the municipality, varies from once a day to once a week in urban communities. | | |
| c) How does the frequency of street cleaning depend upon adjacent land use? | | No | | |
| d) Are streets cleaned for aesthetic reasons or to improve the quality of runoff? (Is it accepted that the quality of the street runoff is dependent upon the frequency of street cleaning?) | | Yes (Yes) | | This could be envisaged |
| e) What type of equipment is used for street cleaning? | | Sweepers, mechanical and manual | | |
| (ii) Sewers a) What is your regular maintenance program for sewers? | | Clergy-Pontoise, once a year. Other 1/3 of system each year | Depends on deposits in sewers which are regularly controlled | Depends on what means the communities possess |
| b) By what methods do you normally clean sewers? | | High Pressure flushing | Hydroynamic & Hydropneumatic | Special equipment is being envisaged |
| c) Do you make a practice of flushing sewers during dry weather? | | Yes | Yes for small dia. pipes. No "large diameter". | Yes |
| d) Do you install catchbasins for street drainage on new sewers? | | No | Yes | Yes |
| e) How often and by what method do you clean catchbasins? | | N/A | | Very variable |
| (iii) Snow Removal a) When removing snow from the road or highway, do you plough it to the side and leave it to accumulate and ultimately melt or do you remove it and dispose of it at a lake/river sewer/snowdump or other? | | Not a problem, when necessary, use NaCl & plough to one side | | |
| b) Is the frequency of snow removal determined by any factors other than quality? | | N/A | | |
| c) What equipment is used for snow removal? | | Trucks with snow plough blades | | |
| d) Has the environmental impact of snow melt water, or content of the de-icing materials or abrasive materials in the snow melt been assessed? Alternatively, has the effect on the treatment plant been assessed in the case of combined sewers? Could you please identify the materials used for de-icing and summarize the result of the assessments. | | d) No NaCl-little effect as snow is infrequent and of short duration | | Partially (de-icing) Abrasives have caused problems at lift station. Yes, in combined systems especially in winter sports area. NaCl. |
| e) Has lead or other heavy metal been identified as a serious snow contaminant? | | No | | |
| 4. Control of Infiltration into sewers a) Are infiltration allowances specified in design manuals or standards? | | No, the standard of July, 70 requires complete watertightness of sewer systems | No | No |
| b) What is the policy for infiltration control? | | Pressure tests before accepting system. TV control with immediate repair | Left to the service dept. to take care of. | Intervention when infiltration presents problems |
| c) What means are used to correct excessive infiltration? | | Joint injection-replacement of piping | Repair of joints | Repair of affected piping |

QUESTIONNAIRE NO. 2
DESIGN PRACTICES OF NEW SEWER SYSTEMS AND
MODIFICATIONS TO EXISTING SYSTEMS

| FRANCE | 1<br>Government | 2<br>Ministry of Agriculture | 3<br>Ministry of Equipment | 4<br>Environment Secretariat |
|---|---|---|---|---|
| 1. Storm Sewer Design<br>a) What storm frequency is required to be used for new sewer systems and what storm duration? | Presently being revised | 10 year storm, average duration 10 to 15 minutes | 10 year storm | 10 year storm |
| b) Is the design storm derived from an intensity/duration/frequency curve? How is the design storm hydrograph derived? | Yes<br>Gaquot formula<br>$i(mm/hr) = a_{(F)} \cdot t^{b(F)}$ | Yes<br>Gaquot formula | Yes circular 1333 | Yes circular 1333 |
| c) Is the design storm frequency/intensity varied for residential areas, commercial & industrial areas, culvert capacities for minor roads, major roads & freeways? | At present no | No | No | No |
| d) Is the design of new storm sewer systems based only on quantity? | | Yes | Yes | Yes |
| e) Is quality considered in the design as well as quantity?<br>(i) is anything being done about improving runoff quality?<br>(ii) is storm runoff treatment anticipated?<br>(iii) is research proceeding into runoff quality & runoff treatment? | It is recognized that storm water is polluted, but at present no treatment is envised (economic restraints) | (i) No<br>(ii) No<br>(iii) Not yet | Not at present<br>(i) No<br>(ii) Depends on (iii)<br>(iii) Yes | (i) Yes<br>(ii) Yes<br>(iii) Yes |
| f) Is snow melt considered in sizing the sewer pipe? | No | No | No | No |
| g) Are new storm sewer systems designed as separate, combined, partially separate or other? Please amplify | New towns-separate systems mandatory. Elsewhere the choice of system is left to the consultants | Separate, except in certain areas which discharge into the Seine-St. Denis | Both, due to decision made in 1933 | No doctrine - it is a question of circumstances |
| h) Are new storm sewer designs based on:<br>(i) open channel or free flow?<br>(ii) pressurized flow?<br>(iii) sewer surcharge allowed but infrequent? | (i) | (i)<br>(iii) | (iii) | (i) |
| 2. Storm Runoff Attenuation<br>a) To reduce the rate of storm runoff, is storm water stored<br>(i) on roofs?<br>(ii) on streets & sidewalks?<br>(iii) on parking lots?<br>(iv) on school grounds?<br>(v) in parks?<br>(vi) in any wall at all? | The Gaquot formula allows for urban area storage | (vi) normally in large retention basins | (vi) large retention basins | (vi) possible but under very exceptional circumstances |
| b) What measures are mandatory in new significant sized constructions or developments in order to restrict strom runoff flows? | Retention basins | Retention basins | Retention basins | This again will depend on particular circumstances |
| c) Is ponding or use of depression storage or infiltration used to restrict the intensity of storm runoffs? | Yes, sometimes to reduce the size of a retention basin | Yes, but the efficiency is dubious, and pollution of groundwater can be serious | As a temporary measure | New regulations may determine important developments in storage basins. |
| d) Is it possible to give quantitive assessment of the attenuation required under 2 (a) & (b), either by depth of water or storm frequency? | No | Yes, by either method provided certain measures are taken in constructing | | |
| 3. Sanitary Sewer Design<br>a) Are new sanitary sewers designed as gravity sewers, pressurized sewers, combination partly gravity, partly pressurized or as vacuum sewers? | Generally gravity. Vacuum systems are permitted but very few installed | Gravity | Gravity | Gravity |
| b) Please outline any experience you may have re pressurized sewers or any on going research you are aware of into pressurized sewers. | | None | Such a system has been in service for several years, and has given very little problem | None |
| c) Please specify what sources of sewage drain into sanitary and storm sewers respectively in the case of partially separated sewers. | No particular measures are taken regarding storm water even in industrial areas. However regulations are tending to become more and more strict. | Sanitary household sewage, industrial waste, wash water. Storm rain water street washings, land drainage, industrial cooling water. | | Sanitary household sewage, industrial waste, wash water. Storm rain water, street washings etc. |
| d) How is the maximum capacity of the sewage treatment plant related to the dry weather flow? | 4 times DWF | 3 times DWF (usual)<br>4 times DWF (short periods) | Theoretically 2 or 3 times DWF; practically up to 5 times DWF | 4 or 5 times DWF |
| 4. Storm Holding Tanks - Combined Sewers<br>a) Are storm holding tanks generally constructed at sewage treatment plants? | No | No | | No |
| b) How is their volume calculated relative to the capacity of the overflow capacity of the plant? | | | | |

**QUESTIONNAIRE NO. 3**
**ABATEMENT AND POLLUTION DUE TO COMBINED SEWER OVERFLOWS**

**FRANCE**

| | 1<br>Government | 2<br>Ministry of Agriculture Local Office | 3<br>Ministry of Equipment Local Office | 4<br>Environmental Secretariat |
|---|---|---|---|---|
| 1. Combined Sewer Overflows are considered:<br>a) major source of pollution<br>b) not significant in relation to others<br>c) not significant for local receiving water<br>Please explain. | | a) | a) | a) |
| 2. Policy re control of overflows:<br>a) no policy established<br>b) policy based on discharge standards (concentration & frequencies)<br>c) policy based on water quality and use of receiving waters<br>d) other Please explain | a) | c) Depending on the other uses of the receiving waters. | a) Left to the PWD to decide | b) |
| 3. Combined Sewer Overflow Regulators<br>Regulators are set to discharge at the following flows (as related to the Interceptor capacity):<br>a) Static regulators - specify most frequently used, up to what flows?<br>b) Dynamic regulators - describe types used, flows? | N/A | No specific regulations | | Retention tanks have been installed on combined systems, and can give problems in maintaining the quality of retained waters |
| c) Are regulators controlled by overflow quality, what types used, operational experience. | | | | |
| d) Research on overflow regulators - if any. | | No | Planned-telemetry is now used and computor control is envisaged in the near future | No, but these could be interesting |
| 4. Computer Controlled Systems Maximizing Storage in Combined Sewers:<br>Are any such systems used currently or planned?<br>What is your attitude towards the above system? | | No | | No |
| 5. Use of Drag Reducing Additives to Increase Sewer Capacities:<br>Are any above additives used or planned to be used?<br>If so, what types are being used or considered?<br>Was impact of additives on waste treatment plant and receiving water evaluated, please specify. | | Yes, sand traps are placed above the overflow weirs | Only side or front weirs presently in use | Strainers are envisaged |
| 6. Selection of Pollution Abatment Schemes:<br>a) Are any other abatement schemes than the above (i.e. Items 1-5) used?<br>Is any of the above schemes preferred? | | | | |
| b) Selection of abatement schemes is done:<br>(i) on the basis of experience, only some promising schemes are considered<br>(ii) a number of abatement schemes are considered in a computerized analysis based on a simulation model<br>(iii) a combination of (i) and (ii) Please specify | | | | |

QUESTIONNAIRE NO. 1
SEWERAGE FUNDAMENTALS

| SWITZERLAND | 1<br>Consultants | 3<br>Federal Water Institute |
|---|---|---|
| 1. Roof Drainage: Is residential roof drainage:<br>a) discharged into storm sewers?<br>b) discharged into street gutters or ditches?<br>c) discharged onto property for seepage into soil?<br>d) used for irrigation?<br>e) disposed of in some other way? | a) & b) | a) |
| 2. Foundation drains: Are these normally connected to:<br>a) storm sewers?<br>b) sanitary sewers?<br>c) combined sewers?<br>d) another disposal system? | a) or c) | a) or c) |
| 3. Cleaning practices:<br>(i) Streets<br>a) are downtown streets swept/washed daily/weekly/monthly? | Swept Daily<br>Washed Weekly | In Zurich, swept 10 times a week, washed as required at irregular intervals |
| b) Are surburban streets swept/washed daily/weekly/monthly? | Swept Daily<br>Washed Monthly | Zurich-swept less often, washed as required |
| c) How does the frequency of street cleaning depend upon adjacent land use? | | No, except close to a building site |
| d) Are streets cleaned for aesthetic reasons or to improve the quality of runoff? (Is it accepted that the quality of the street runoff is dependent upon the frequency of street cleaning?) | d) Aesthetic reasons, in winter to get rid of sand and salt<br>Not accepted | Aesthetic & hygenic reasons |
| e) What type of equipment is used for street cleaning? | e) Brushes & mechanical cleaners | e) Mechanical sweepers & washers |
| (ii) Sewers<br>a) What is your regular maintenance program for sewers? | Depends on Municipality | Depends on the particular situation |
| b) By what methods do you normally clean sewers | HP flushing, pigs & rodding | HP flushing, rodding & pigs |
| c) Do you make a practice of flushing sewers during dry weather? | Not to our knowledge | |
| d) Do you install catchbasins for street drainage on new sewers? | Yes | Yes |
| e) How often and by what method do you clean catchbasins? | Hand shovel or suction tanker | Suction tankers, 1 to 3 times a year |
| (iii) Snow Removal<br>a) When removing snow from the road or highway, do you plough it to the side and leave it to accumulate and ultimately melt or do you remove it and dispose of it at a lake/river sewer/snowdump or other? | Plough it to one side | Usually ploughed to one side. Removed if very dirty or obstruction to traffic |
| b) Is the frequency of snow removal determined by any factors other than quality? | Safety | Safety |
| c) What equipment is used for snow removal? | Snow ploughs, tractors, trucks | Snow ploughs, trucks, manual labour |
| d) Has the environmental impact of snow melt water, or content of the de-icing materials or abrasive materials in the snow melt been assessed? Alternatively, has the effect on the treatment plant been assessed in the case of combined sewers? Could you please identify the materials used for de-icing and summarize the result of the assessments. | No, but abrasives play a role, and upset the working of treatment plants | Yes<br>Combined systems - no upset in plants<br>Very low temp - NaCl<br>Otherwise - CaCl |
| e) Has lead or other heavy metal been identified as a serious snow contaminant? | Yes | |
| 4. Control of Infiltration into sewers<br>a) Are infiltration allowances specified in design manuals or standards? | Yes - 0.3 $l/m^2$ of piping hour under 30 cm of water pressure | Yes |
| b) What is the policy for infiltration control? | No effective policy | Insistence upon piping being practically watertight |
| c) What means are used to correct excessive infiltration? | Repair joints, surround with concrete, local repairs | |

QUESTIONNAIRE NO. 2
DESIGN PRACTICES OF NEW SEWER SYSTEMS AND MODIFICATIONS TO EXISTING SYSTEMS

SWITZERLAND

| | 1<br>Consultants | 2<br>Provincial Highway Authority | 3<br>Federal Water Institute |
|---|---|---|---|
| 1. Storm Sewer Design<br>a) What storm frequency is required to be used for new sewer systems and what storm duration? | 10 year storm<br>15 min duration | 10 year storm<br>Duration is proportional to the intensity | Rural areas - 5 year<br>Urban areas - 10 year<br>Cities - 20 year<br>Duration depends on runoff time. |
| b) Is the design storm derived from an intensity/duration/frequency curve? How is the design storm hydrograph derived? | Yes, by regions<br>On the basis of the curves, following SNV standards | Yes, by regions. On the basis of the curves, following SNV standards | Yes, $Q=F_{RED} \times I$ (l/sec.)<br>F=reduced surface, of zone under consideration (ha)<br>i=intensity (litres/sec/ha.) |
| c) Is the design storm frequency/intensity varied for residential areas, commercial & industrial areas, culvert capacities for minor roads, major roads & freeways? | No | Yes, only variation is if the construction is urban or rural | Yes, for residential, commercial & industrial zones |
| d) Is the design of new storm sewer systems based only on quantity? | No, just by coefficients for runoff (function of ground cover and slope) | No, depends also on runoff time, on the catchment area and on the road surface | Yes, but 30 cm min. |
| e) Is quality considered in the design as well as quantity?<br>(i) Is anything being done about improving runoff quality?<br>(ii) Is storm runoff treatment anticipated?<br>(iii) Is research proceeding into runoff quality & runoff treatment? | (i) no<br>(ii) no<br>(iii) no | | (i) -<br>(ii) -<br>(iii) yes |
| f) Is snow melt considered in sizing the sewer pipe? | No | | No |
| g) Are new storm sewer systems designed as separate, combined, partially separate or other? Please amplify. | New areas-separate.<br>Extensions of old areas conform to existing system | For autoroutes, virtually always independent | Probably 95% combined-result of practice, not a "doctrine" |
| h) Are new storm sewer designs based on:<br>(i) open channel or free flow?<br>(ii) pressurized flow?<br>(iii) sewer surcharge allowed but infrequent? | (i) | (i) | (i) |
| 2. Storm Runoff Attenuation<br>a) To reduce the rate of storm runoff, is storm water stored<br>(i) on roofs?<br>(ii) on streets & sidewalks?<br>(iii) on parking lots?<br>(iv) on school grounds?<br>(v) in parks?<br>(vi) in any wall at all? | No storage | (vi) by using "flood reducing tanks" | In general, there is no storage |
| b) What measures are mandatory in new significant sized constructions or developments in order to restrict storm runoff flows? | Retention basins | | Overflows, with or without retention basins |
| c) Is ponding or use of depression storage or infiltration used to restrict the intensity of storm runoffs? | Yes | Yes | |
| d) Is it possible to give quantitive assessment of the attenuation required under 2 (a) & (b), either by depth of water or storm frequency? | Theoretically possible but not effective | | For overflows, evaluation is possible |

| | 1<br>Consultants | 2<br>Provincial Highway Authority | 3<br>Federal Water Institute |
|---|---|---|---|
| 3. <u>Sanitary Sewer Design</u><br>a) Are new sanitary sewers designed as gravity sewers, pressurized sewers, combination partly gravity, partly pressurized or as vacuum sewers? | Gravity | | Gravity |
| b) Would you please outline any experience you may have re pressurized sewers or any on going research you are aware of into pressurized sewers? | None | | None |
| c) Would you please specify what sources of sewage drain into sanitary and storm sewers respectively in the case of partially separated sewers? | Only distinctions<br>EV-domestic & industrial<br>EP-rainwater<br>KI-industrial (special case) | | |
| d) How is the maximum capacity of the sewage treatment plant related to the dry weather flow? | 5 x DWF | | 4 x DWF for primary settlement in existing plants |
| 4. <u>Storm Holding Tanks - Combined Sewers</u><br>a) Are storm holding tanks generally constructed at sewage treatment plants? | Yes | | Yes |
| b) How is their volume calculated relative to the capacity of the overflow capacity of the plant? | Difference between Q entering & Q (biologically admissible) | | |
| c) Is the quality of sewage routed to the tank considered in the design of the tank? | No | | |
| d) Is provision made for treating the capacity of the storm holding tank:<br>(i) within the tank?<br>(ii) separate treatment plant?<br>(iii) by pumping back to main plant?<br>(iv) is ozone used for the treatment?<br>(v) how much is treated and how is it discharged?<br>(vi) would you please describe the plant and process used for d(i) or (ii) or (iv). | Yes (iii)<br>(v) the volume of the tank | | Apart from retention & settlement, there is no treatment of storm water |
| e) What is the prime factor limiting the detention period in a storm holding tank?<br>a) construction costs?<br>b) oxygen depletion?<br>c) probability of new storm occurrence? Please amplify | a) | | Capacity of the treatment |
| 5. <u>Storm Runoff Storage</u><br>a) Is detention storage provided for storm sewers either in-system of off-system, as a single storage structure one cell or multi-cell or as a system of storage structures? | In-system | | Retention basin |
| b) Is detention storage provided in natural depressions or in reservoirs (with embankments), fully enclosed tank above ground, below ground or below water? | Tanks below ground | | Open or closed tanks |
| c) If not as outlined in 5(a) or (b), by what method is storage provided? | None | | |

| | 1<br>Consultants | 2<br>Provincial Highway Authority | 3<br>Federal Water Institute |
|---|---|---|---|
| 6. What is main criterion considered in locating storm water storage structures?<br>a) public acceptance<br>b) land availability<br>c) sewer system capacity<br>d) close to the waste treatment plant<br>e) other (please specify) | (c)<br>& topography<br>& proximity to the receiving waters. | | Proximity to the receiving waters |
| 7. Treatment of Storm Runoff and Overflows<br>a) Combined sewers<br>Is treatment of storm runoff and/or overflows:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered?<br>What equipment is used? | (i) yes<br>(ii) yes<br>(iii) yes<br>(iv) -<br>conventional systems | | |
| b) Storm Sewers<br>Is treatment of Storm Sewers:<br>(i) currently used<br>(ii) required by regulations<br>(iii) currently planned<br>(iv) under study<br>If yes, to any of the above items, what treatment processes are considered?<br>What equipment is used? | (i)<br>(ii)<br>(iii) No<br>(iv) | | |
| 8. Would you please outline operational problems which have arisen with storm runoff storage with respect to solids removal or odour control? | Difficulty in collecting the waste, and general maintenance. Also in containing odours | | |
| 9. Field Studies of Sewer Systems<br>a) Field studies carried out to support:<br>(i) design of new sewers (storm or combined)<br>(ii) analysis of existing sewer systems<br>(iii) design of overflow control schemes<br>(iv) other - please specify | (i) & (ii) and to examine the functioning of existing systems, to measure discharges, & for maintenance | | Generally no field studies |
| b) Field studies are not presently anticipated because:<br>(i) sufficient information on sewer systems available<br>(ii) mathematical simulation models eliminate the need for above studies.<br>(iii) other - please specify | | | A serious study takes too much time |
| c) In a typical field study the following phenomena are recorded:<br>(i) flow rates<br>(ii) precipitation<br>(iii) water quality<br>(iv) other - please specify | (i) & (iii) | | A study for (i), (ii) & (iii) is being prepared |
| For the above please specify most successful equipment and methods used, their accuracy, operational equipment. Are there any data covering all items and available (eventually for different land use)? | Fluorescene<br>Mirrors<br>Flowmeters<br>Chemical determination<br>No | | |

QUESTIONNAIRE NO. 3
ABATEMENT AND POLLUTION DUE TO
COMBINED SEWER OVERFLOWS

| SWITZERLAND | 1<br>Consultants | 3<br>Federal Water Institute |
|---|---|---|
| 1. Combined Sewer Overflows are considered:<br>a) major source of pollution<br>b) not significant in relation to others<br>c) not significant for local receiving water<br>Please explain. | b) & c) | a) |
| 2. Policy re control of Overflows:<br>a) no policy established<br>b) policy based on discharge standards (concentrations & frequencies)<br>c) policy based on water quality and use of receiving waters<br>d) Other Please explain | b) | a) envisaged in future<br>b) under discussion<br>c) yes-among others<br>d) - |
| 3. Combined Sewer Overflow Regulators<br>Regulators are set to discharge at the following flows (as related to the Interceptor capacity):<br>a) Static regulators - specify most frequently used, up to what flows?<br>b) Dynamic regulators - describe types used, flows | a) -<br>b) i) leaping weir<br>ii) diverting blade<br>(single or double) | Generally none |
| c) Are regulators controlled by overflow quality, what types used, operational experience? | c) no | |
| d) Research on overflow regulators - if any. | | None in operation<br>Urgently required |
| 4. Computer Controlled Systems Maximizing Storage in Combined Sewers:<br>Are any such systems used currently or planned?<br>What is your attitude towards the above system? | No | |
| 5. Use of Drag Reducing Additives to Increase Sewer Capacities:<br>Are any above additives used or planned to be used?<br>If so, what types are being used or considered<br>Was impact of additives on waste treatment plant and receiving water evaluated, please specify. | | |
| 6. Selection of Pollution Abatement Schemes:<br>a) Are any other abatement schemes than the above (i.e. Items 1-5) used?<br>Is any of the above schemes preferred? | | |
| b) Selection of abatement schemes is done:<br>(i) on the basis of experience, only some promising schemes are considered<br>(ii) a number of abatement schemes are considered in a computerized analysis based on a simulation model<br>(iii) a combination of (i) and (ii) Please specify. | | |